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EXAMINATION of the INFLUENCE of COATINGS on THIN SUPERALLOY SECTIONS

Volume II

DETAILED PROCEDURES and DATA

by
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16. Abstract

The effects of an aluminide coating, Codep B-1, and of section thickness were investigated on two cast nickel base superalloys, Rene 80 and Rene 120. Cast section thicknesses ranged from 0.038 cm to 0.15 cm. Simulated engine exposures for 1000 hours at 899C or 982C in a jet fuel burner rig with cyclic air cooling were studied, as were the effects of surface machining before coating and re-machining and re-coating after exposures. The properties evaluated included tensile at R.T., 871C and 982C, stress rupture at 760C, 871C, 982C and 1093C, high cycle mechanical fatigue at R.T., and thermal fatigue with a 1093C peak temperature.

Thin sections had tensile strengths similar to standard size bars up to 871C and lower strengths at 982C and above, with equivalent elongation. Stress rupture life was lower for thin sections at all test conditions. The aluminide coating lowered tensile and rupture strengths up to 871C, with greater effects on thinner specimens. Elevated temperature exposure lowered tensile and rupture strengths of thinner specimens at the lower test temperatures. Surface machining had little effect on properties, but re-machining after exposure reduced thickness and increased metallurgical changes enough to lower properties at most test conditions.

Volume I, Description and Analysis, CR-134791, includes the summary, introduction, description of tests and results with full discussion, conclusions and recommendations.

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FOREWORD

This report is Volume II of a two volume report prepared by the Aircraft Engine Group of the General Electric Company under National Aeronautics and Space Administration Contract No. NAS3-16759, evaluating the effects of protective coating and section thickness on the mechanical properties of cast nickel-base superalloys. Volume I includes the summary introduction, description of tests and results with full discussion, conclusions and recommendations. Volume II is a detailed description of materials and test procedures and a complete tabulation of all test results.

The program was sponsored by the Lewis Directorate, U.S. Army Air Mobility Research and Development Laboratory, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio with Mr. John P. Merutka as Program Manager. The General Electric Company Program Manager was Mr. E. J. Kerzicnik. The author gratefully acknowledges the support of the Program Managers and the General Electric Company personnel who contributed to the program.

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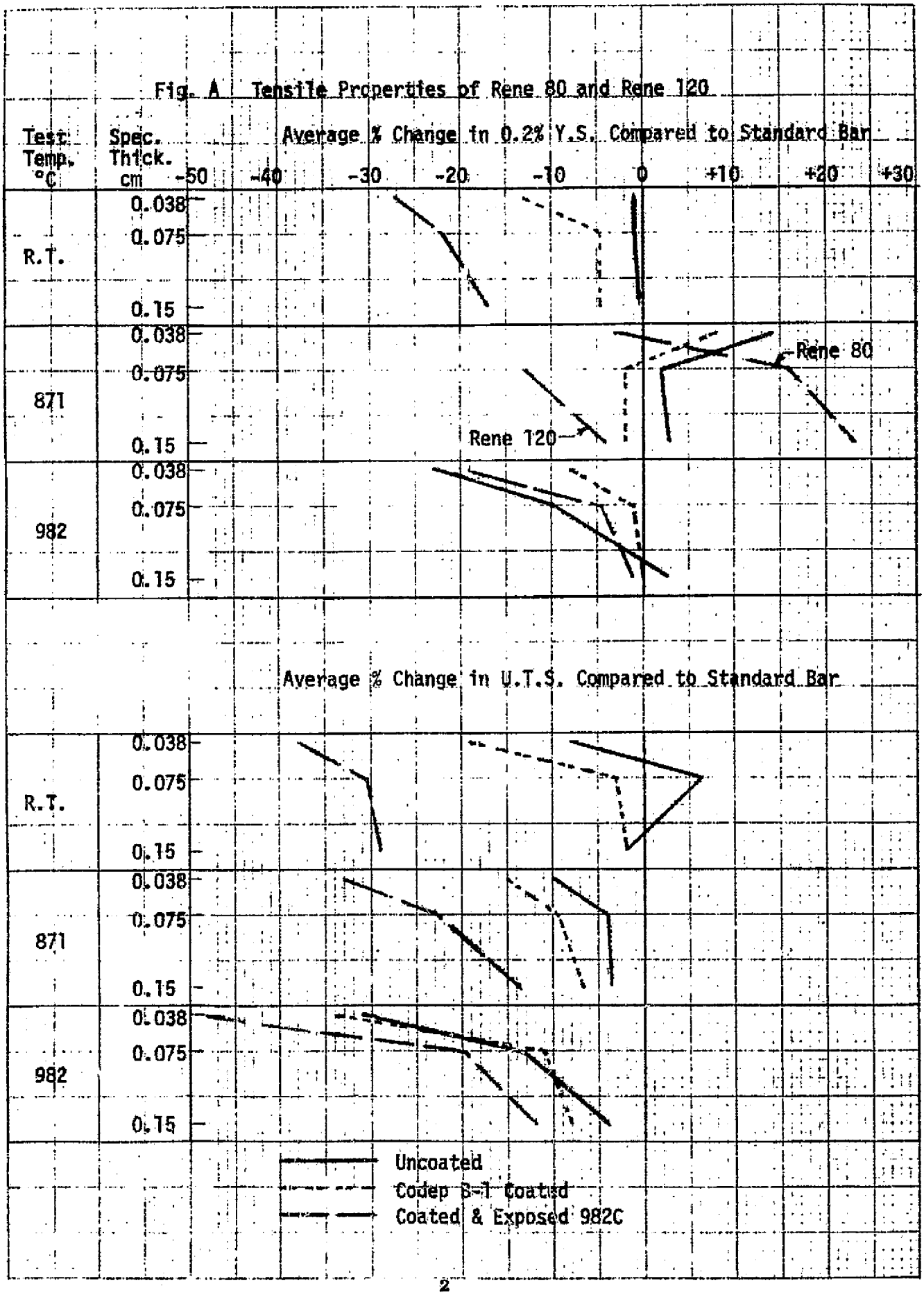
SUMMARY

The effects of an aluminide coating, Codep B-1, and of section thickness were investigated on two cast nickel base superalloys, Rene 80 and Rene 120. Cast section thicknesses ranged from 0.038 cm to 0.15 cm which are in the region of many present turbine blade thicknesses. The coating is necessary to extend turbine blade life by providing oxidation and hot corrosion protection. Simulated engine exposures for 1000 hours at 899C or 982C in a jet fuel burner rig (0.05M) with cyclic air cooling were studied, as were the effects of surface machining before coating and re-machining and re-coating after exposures. The properties evaluated included tensile at R.T., 871C and 982C, stress rupture at 760C, 871C, 982C and 1093C, high cycle mechanical fatigue at R.T., and thermal fatigue with a 1093C peak temperature. In the following summary of results, the data from an earlier program[1] on Rene 80 is incorporated wherever possible. All coated specimen data discussion is based on stresses calculated from the original metal thickness before coating.

Tensile Properties. The effects of coating, section thickness and exposure are quite similar for both alloys. Fig. A shows the variation in 0.2% Y.S. and U.T.S. with section thickness and temperature. The strength is expressed as % of the average strength of bare and coated standard size (0.64 cm diameter) bars. Bare specimen Y.S. is not affected by thickness at R.T., but is higher for the 0.038 cm specimens at 871C and lower at 982C. Coating lowers Y.S. about 5% at R.T. and 871C, and raises Y.S. for the thinner sections at 982C. The 982C exposure lowers Y.S. in all cases except for Rene 80 thicker sections at 871C (the only point of difference from Rene 120). In all cases the exposure causes lower Y.S. for thinner sections.

Fig. A Tensile Properties of Rene 80 and Rene 120



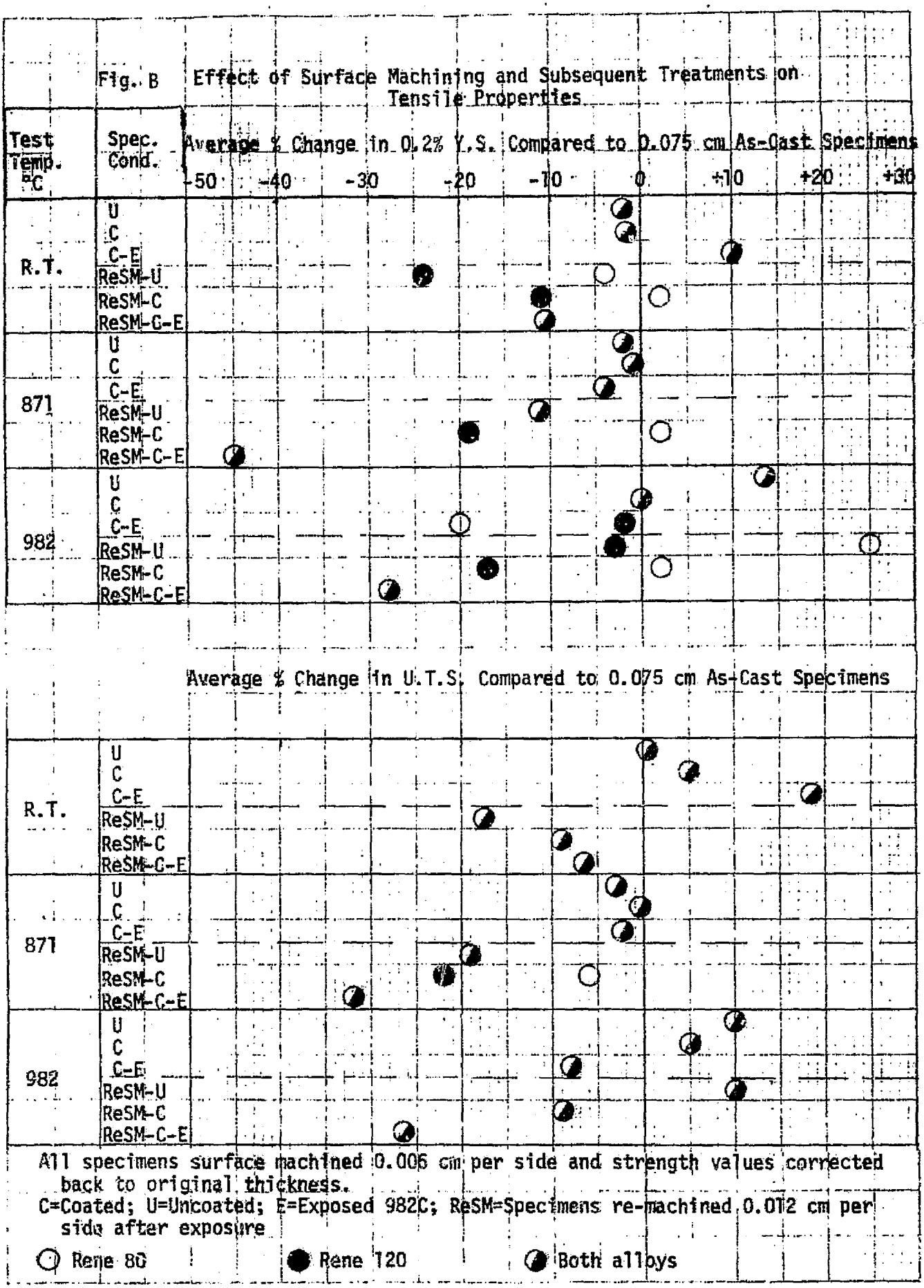
Except for the 0.075 cm uncoated specimens at R.T., the thinner the section, the lower the U.T.S. for all conditions. For bare and coated specimens, the higher the temperature, the lower the strength compared to standard size bars. Coating reduces U.T.S. at R.T. and 871C, except for the 0.075 cm specimen at 982C. Exposure at 982C significantly reduces U.T.S. at R.T., with smaller losses as the temperature increases, and smaller losses for thicker specimens.

Elongations of the thin sections are equivalent to those of standard size bars. Coating lowers elongations of the 0.038 cm specimens, with lesser effects on the thicker specimens. The 982C exposure reduces elongation at all temperatures, with the greatest loss at 871C.

A limited number of coarse grained specimens were tested at R.T. and 871C (0.075 cm thickness of Rene 80 and 0.15 cm thickness of Rene 120). Grain size was 2 to 4X the normal specimens. The coarse grain material has higher properties at 871C than the normal grain size material of the same thickness for both alloys, and at R.T. for Rene 80. The coarse grain Rene 120 has lower properties at R.T.

The effects of removing the as-cast surface of the 0.075 cm specimens by machining, before and after exposure are shown in Fig. B for bare, coated and coated plus ~1000 hour exposure at 982C specimens. The data is "corrected" for thickness back to the original dimension. On this basis, the initial surface machining (SM) has little effect on strengths for bare or coated specimens. After exposure, the SM specimens have higher R.T. strengths and lower elevated temperature strengths. After exposure re-SM results in lower R.T. and 871C strengths, but improves U.T.S. for both alloys and Y.S. for Rene 80 at 982C. The re-treatment and coating returns Y.S. of Rene 80 to original levels at all temperatures, while Rene 120 is not improved. The second 982C exposure causes relative strength losses, particularly at elevated temperature. Elongations are less affected, and in most cases are somewhat higher for the surface machined samples compared to the as-cast 0.075 cm conditions.

Fig. 8 Effect of Surface Machining and Subsequent Treatments on Tensile Properties



All specimens surface machined 0.006 cm per side and strength values corrected back to original thickness.

C=Coated; U=Uncoated; E=Exposed 982C; ReSM=Specimens re-machined 0.012 cm per side after exposure

○ Rene 80 ● Rene 120 ◑ Both alloys

Stress Rupture Properties. The rupture lives of the two alloys expressed as a percentage of the standard size bar life are shown in Fig. C. The differences in behavior are greater than noted in tensile strengths. For both alloys, bare or coated, the thinner the specimen, the lower the rupture life.

Maximum life for the 0.038 cm Rene 80 bare specimens is ~30% at 760C and 1093C, while the minimum is ~2% at 982C. The fact that life was lower at 760C for the thinner sections in spite of their beneficial fine grain size indicates that the geometry effect on fracture is of considerable magnitude.

Coating lowers life for both alloys at all thicknesses at 760C and 871C and for high stress at 982C. The low stress at 982C and the 1093C tests show little effect. It should be noted that if the stress is based on the sound metal thickness below the coating, there is no reduction in life due to coating except at 760C.

Exposure further lowers the life of both alloys at 760C and 871C, with smaller, or no losses at 982C (low stress) and 1093C. Rene 120 thin sections generally have lower relative lives than Rene 80 except for the 982C, high stress, bare condition.

Coarse grained specimens, as described previously, were stress rupture tested at 871C and 1093C. Bare or coated, the coarse grained material have lower life at 871C (by 8 to 38%) and greater life at 1093C (by 20 to 100%) compared to standard bar life.

The effects of SM and re-treatments (described previously) on stress rupture life are shown in Fig. D. Lives are corrected for section thickness and compared to as-cast 0.075 cm specimen lives for the equivalent condition. Because of the greater variability in the rupture data compared to the tensile data, and the greater effect of section thickness on rupture life, there is a greater spread in the results.

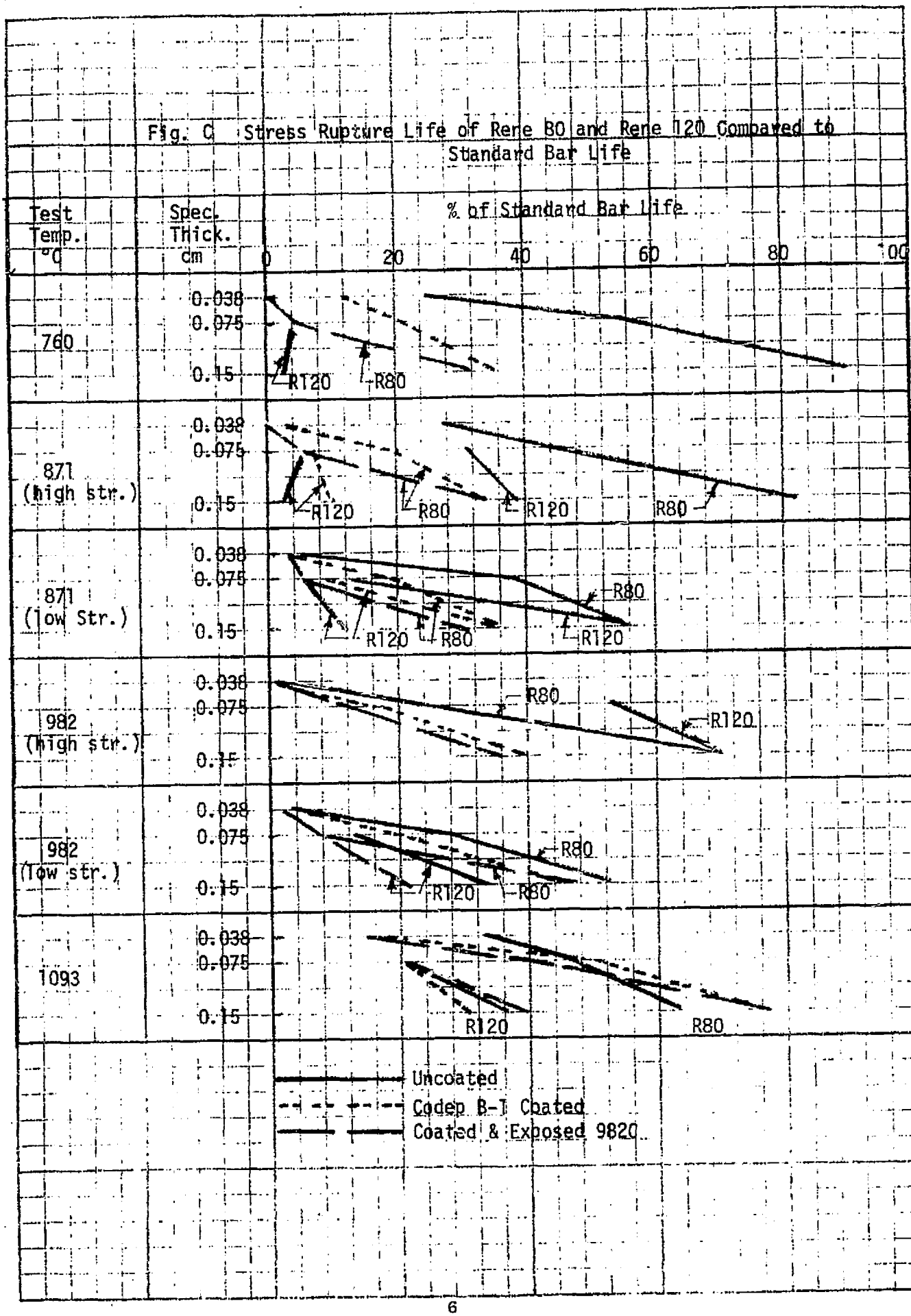


Fig. C Stress Rupture Life of Rene 80 and Rene 120 Compared to Standard Bar Life

General conclusions are that the SM lowers lives at 760C and 871C and raises lives at 982C and 1093C, bare or coated. Relative life after exposure is lower for Rene 80 and higher for Rene 120 at the three higher temperatures, and the reverse at 760C. Re-surface machined specimens after exposure, whether bare, re-treated and coated or re-exposed at 982C, have lower lives than the respective specimens before re-SM. Although the 0.075 cm specimens were not initially aided in rupture life by the re-coating treatment, the improved life occurring in thicker specimens (>0.075 cm) with exposure, combined with the additional environmental protection afforded by the new coating make the re-treatment process more desirable.

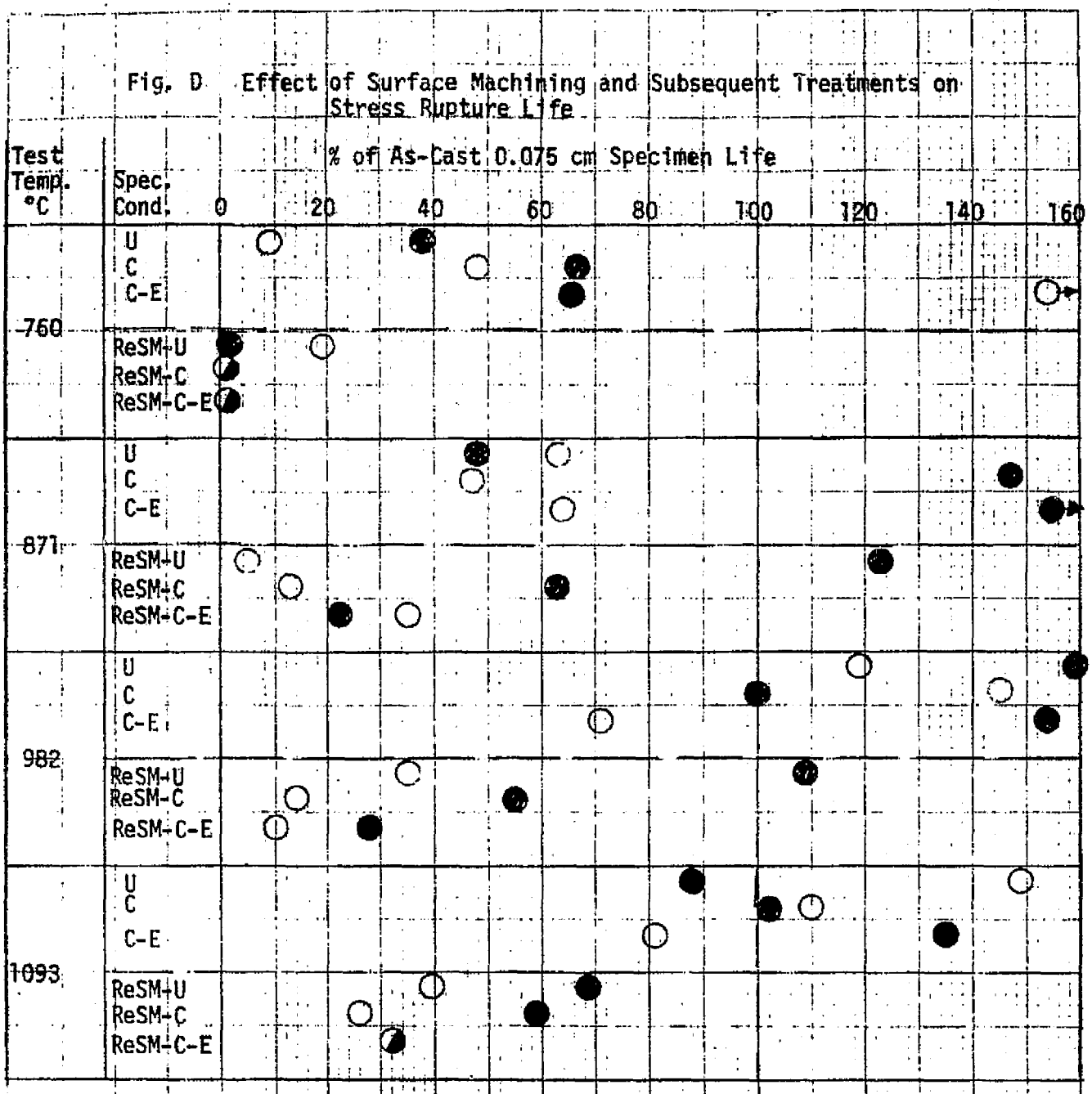
Thermal Fatigue. With a 1093C peak, 204C minimum temperature, 10 second heating time, 50 second hold time and 20 second cooling time thermal cycle, no normal thermal fatigue cracks could be produced in the round 0.075 cm thick coated or coated/982C exposed specimens of either alloy up to 4000 cycles.

High Cycle Mechanical Fatigue. The 10^7 cycle, reversed bending fatigue strengths for Rene 120 are:

Uncoated	269 MN/m^2
Coated	269 "
Coated, exposed 982C	286 "

The coating and exposure have virtually no effect (with stress measured at exterior of coated samples). These values are lower than previously found for Rene 80 by 30% (uncoated) to 7% (coated and exposed).

Fig. D Effect of Surface Machining and Subsequent Treatments on Stress Rupture Life



All specimens surface machined 0.006 cm per side and strength values corrected back to original thickness.

C=Coated; U=Uncoated; E=Exposed 982C; ReSM=Specimens re-machined 0.012 cm per side after exposure

○ Rene 80 ● Rene 120 ◐ Both alloys

MATERIAL AND SPECIMEN PREPARATION

Castings and Specimen Identification

The casting design and process parameters were chosen to simulate thin-walled turbine blades as closely as possible. Figure 1 shows the casting, which is the same as that proven satisfactory in the initial program.[1] The size is representative of several air-cooled turbine blades. While most blades would have internal structures, they would interfere with obtaining uniform specimens of sufficient size here. The rounded edge resembles a blade leading edge, and provides specimens for thermal fatigue tests. Each of the flat faces provides a single sheet-type specimen suitable for tensile, stress rupture and mechanical fatigue tests. This casting design was not capable of producing the thinnest specimens desired, 0.038 cm. After several re-design attempts, the casting shown in Figure 2 was successful for Rene 80. Due to the low yield of acceptable Rene 120 castings, only a few were made. Compared to the original casting, the width and depth were reduced considerably, the length reduced slightly, and the gate was slit and fed along the entire length of one side, rather than from two points.

A description of the casting process for the original design casting, Figure 1, provided by the vendor, Jetshapes, Inc. is as follows:

A single cavity die was used with different thickness cores to make the different wall thicknesses (0.075 cm and 0.15 cm). Gating was cut in the die. After injection and dressing, 16 pieces were set up per sprue (4 pieces per runner). A standard shell system was employed for mold making. Pour temperatures of 1454-1482C were used, with a mold temperature of 1093C. After casting, the ceramic was removed and specimens cut off from the gating system, sand blasted to clean and remove cores, marked with identification numbers, flat sides slit from castings and inspected (visual, standard fluor-

-escent penetrant and x-ray radiographic methods required in specifications for airfoils). The radiographs were used for grain size inspection as well as for defect detection. In no case was any other operation performed on the flat surfaces of the castings.

An identification numbering system was used such that the complete history of each piece could be established. A four (or five) digit number was serially assigned to each mold pour.

A number (1,2,3,4) represents the position around the group of 4 pieces on each runner, with No. 1 the outer and No. 3 the inner position. A letter (A,B, C,D) indicates from which of the 4 clusters the casting comes. The position letter and number were placed after the pour number for Rene 80 and in front of the pour number for Rene 120. Unfortunately, no distinction was made between the inner and outer facing sides of the castings when the flat sides were cut apart. Therefore, a final arbitrary letter (A or B) was added when both sides of a casting were sound to the previous identification to indicate the sides of the casting. A full number, such as 4541A1A, describes the flat specimen taken from the "A" side of the first casting in the first position in the mold from pour number 4541. Some specimens were obtained for this work which were made in an identical fashion by the same vendor, but originally intended for a different program. These were not numbered in the system above, but had either simple serial number, or none.

The 0.038 cm castings, Figure 2, were processed in a similar fashion, except that only one level of the cluster of 4 castings was used per mold. Consequently, the identification lacks the number after the letter designating the stack position in the mold.

In a few instances, pieces were received with incorrect markings, such as a position letter not A,B,C or D, or three pieces having the same pour and position identification, where only two are possible (each side of the casting). Since no means existed to correct the identification, such mismarked specimens are reported as such. A list of all the pour numbers for both alloys is included in Table I. Standard test bars, 0.64 cm diameter cast with the vendor's normal practice were obtained for each heat of material used for thin castings.

Chemical Composition

Chemical analyses were supplied by the vendor for each master heat, and for several individual pieces, and are given in Table II and III for Rene 80 and Rene 120, respectively. It was intended to obtain all the required data for Rene 80 from a single heat and compare results to the prior program[1] but insufficient material was available from the initial heat (B322). The second heat, B353, was required for producing the majority of the 0.038 cm thick specimens and for investigating the effects of surface machining on tensile properties of the 0.075cm material. Two heatsof Rene 120 were intentionally used to obtain verification of the property variations due to coating, exposure and thickness. Only the second heat, B415, was used for surface machining effects.

The majority of the analyses were performed by normal optical spectroscopy, and some for Rene 120 specimens were made by x-ray fluorescence analysis. In all cases, the master heat and standard size test bar analyses were within the specifications. The thin specimens are more difficult to measure with the techniques that had been developed for thick pieces. One of the Rene 80 thin specimens showed 0.06% low on the Mo+W requirement (although the indiv-

idual Mo and W values were acceptable), and two of the Rene 120 thin specimens appeared to be 0.01 and 0.02% low on Al + Ti content (again, individual Al and Ti values were acceptable). Based on the more exhaustive chemical analysis comparisons performed in the prior program,[1] it was concluded that there was no reason to believe that the thin specimens were not actually of proper composition.

The PhaComp control number, N_{v3}, requirement was met in all heats. Presumably, a PhaComp number, similar to that described in Ref. 2, below the maximum listed for each alloy will avoid the formation of undesirable intermetallic compounds during operation or elevated temperatures exposures.

Test Specimen Design and Preparation

Upon receipt of the cast pieces, each one was measured in thickness in three spots along the expected location of the gage length of the mechanical test specimen to be machined. Samples of each thickness of each alloy were re-inspected by fluorescent penetrant and x-ray radiography, and were found in agreement with vendor's inspection. As a check on the grain size indicated by the radiographs, several specimens were macroetched*. Examples of the appearance of some of them are given in Figure 3.

Each of the 0.15cm specimens shown in Figure 3 had columnar grains radiating from one of the gating areas, in agreement with the radiographs. When the coarse grained area could be avoided in subsequent specimen machining, the specimen was accepted, otherwise the specimens were rejected, except for those of Rene 120 specifically selected to investigate the effect of grain size. The majority of 0.15cm specimens did not have columnar grains. None of the 0.075cm or 0.038cm specimens had columnar grains. The average grain size

* Macroetch solution: 100 ml HCl, 50 ml H_2O_2, 100 ml H_2O.

in the test sections was~0.015cm for the 0.038cm castings, ~0.035cm for the 0.075cm castings, ~0.07cm for the 0.15cm castings and ~0.07cm to 0.16cm for the standard size bars, all are within the required grain size range.

Surface finish measurements were made on representative pieces, and the results are in Table IV. Finishes were relatively uniform and on the average close to the value of ~70 rms quoted by the vender for normal turbine blade castings and for specimens in the prior program.[1]

The specimen used for tensile and stress rupture testing is the same as used previously [1] and is shown in Figure 4. Some specimens had to be made from slightly shorter blanks, leaving less material between the holes and the ends. No specimens failed by shearing the remaining metal, although several did fracture across the hole. Test specimens were machined at two different sources, using essentially the same technique. Holes were drilled first in the blanks, a group of specimens was clamped using the holes as locators, the contour was ground, specimens were unclamped and the edges cleaned. The faces of the specimens were not touched. At this point, many of the thin specimens still were somewhat bowed as produced by the casting. Although not indicated on Figure 4, the maximum permissible bow was required to be no greater than 0.035cm over the total length of the specimen. The specimens were flattened by stacking and weighting during the initial step of the heat treatment. All bowed pieces were acceptable after heat treatment.

Unfortunately, some of the first specimens machined had part or all of their identification numbers removes when the blanks were cut to the proper length. These were re-identified by a process of elimination, using the remaining part of the number and the exact thickness measurement

distribution as indicators. While the majority of the specimens were undoubtedly properly re-identified, all such specimens were marked with a ? before their number. The thickness at three points along the gage section were measured and recorded.

For thermal fatigue testing, the rounded "leading edge" of the casting, Figure 1, was used, ground to a depth of 0.762cm from the edge. After complete heat treatment, its length was cut to 5.1cm and a flat piece, 0.15cm thick, of Rene 80 was TIG welded to the back to provide restraint during the thermal fatigue testing. No structural changes near the leading edge were caused by the welding.

The standard size test bars, 0.64cm diameter, were cast with threaded ends. In order to insure concentricity of the gage secion, all bars were machined on centers established by the thread locations, with the minimum material removed from the gage section to attain concentricity. The resulting gage section diameters were generally about 0.60 to 0.62cm.

After the contour machining of the flat specimens, the depth machining of the thermal fatigue specimens and the center machining of the standard bars, the material was heat treated as follows:

Rene 80 1218C, 2 hours, in vacuum, rapid cool
1093C, 4 hours, in vacuum, rapid cool

Rene 120 1204C, 2 hours, in vacuum, rapid cool.

At this point, the 0.075cm thick specimens of each alloy requiring surface metal removal were machined by taping to the bed of a surface grinder and longitudinally grinding the required 0.006cm from each side.

The preceding heat treatments were performed by three different sources. All sources had the proper equipment and controls and met the requirement of a maximum depth of alloy/carbide depletion of 0.0025cm.

The next step in the heat treatment process is identical to the Codep B-1 coating thermal cycle and was performed as such, with specimens meant to be uncoated masked and put through the actual coating cycle with specimens being coated (see following section):

Rene 80: 1052C, 4 hours (slow cool)

Rene 120: 1080C, 4 hours (slow cool)

The remainder of the heat treatments are less critical than the preceding steps, and were run at the same three locations as for the initial treatments:

Rene 80: 843C, 16 hours, in vacuum

Rene 120: 1080C, 15 minutes, in vacuum, rapid cool
927C, 8 hours, in vacuum
760C, 16 hours, in vacuum

After processing, the thickness of each thin section specimen was measured at the same three points along the gage section as initially measured. No change occurred for the bare specimens. The increase in thickness of the coated specimens was noted for use in later stress calculations.

Coating

The Codep B-1 coating process uses an aluminum-containing powder and an activator in a pack process, in hydrogen, at the temperatures listed in the above section. Heating and cooling rates are rather slow, but the normal thermal cycle is already included as an integral part of the alloy heat treatment. The coating process forms an NiAl layer, with included fine Al_2O_3 particles, on the surface with a "fingered" multi-phase diffusion zone below

the NiAl surface layer. The depth of the diffusion zone is normally about the same as the thickness of the NiAl layer.

The required average total coating thickness (diffusion zone + NiAl layer) is 0.00295cm so 0.00635cm. This is to be metallographically determined per the coating specification, by cutting samples from each coating run.

In the prior work [1] and for the first coating runs in the present program, each individual specimen was checked using a Microderm MD4 coating thickness gage, calibrated on metallographically measured samples. These values, and other data have shown extremely uniform coating thicknesses within each run. Therefore, later coating runs were checked by the specification method only. A further guide was the thickness measurements before and after coating at three points on every sample. The range of thicknesses found on various Rene 80 coating runs (on as-cast or machined surfaces) was 0.0041 cm to 0.0053cm. For Rene 120, the range of thicknesses was somewhat greater, 0.0034cm to 0.0064cm, for different runs. Two different sources were used for coating, with several runs at each. It would have been more desirable to have all specimens of each alloy coated simultaneously, but scheduling problems prevented this. All coatings were within the specification thickness requirements. Specimens which were re-coated after initial exposure and re-surface machining were given the full heat treatment of the respective alloys with the coating performed in the appropriate sequence.

The coating structure and detailed compositional analyses will be presented later under "Metallurgical Analysis". Briefly, the coating outer layers were verified as NiAl, with some entrapped αAl_2O_3 particles, by x-ray diffraction for both base alloys. Electron microprobe analysis revealed maximum Al contents in the outer layer of 25 to 34%, with the usual amounts of Cr, Ti and other elements. Together with the metallographic inspection, the coatings proved to be normal and acceptable.

EXPOSURE AND TEST PROCEDURES

Exposures

The 1000 hour exposures at 899C and 98C were accomplished using the same burner rigs and techniques as previously reported, [1] JP-5 fuel was burned with an air fuel ratio of 30:1. The velocity of the products of combustion passing the specimens was from 6 to 20 meters per second. Specimens were placed vertically in a fixture which rotated at 30 rpm. The slots in which the pieces were placed could hold a single specimen 0.15cm thick, or two specimens 0.075cm or less. When two specimens were placed in the same slot, they were separated by 0.025cm shims at each end to permit circulation of the gases around both pieces. Temperature was controlled from a thermocouple above the top center of the rotating fixture. Calibration of the control thermocouple was made by comparing to thermocouples placed at three locations on a specimen in a trial run, in which the rotating shaft had slip rings to feed out readings during rotation. Variation up and down specimens during rotation did not exceed ±6C. Specimens were removed from the rig and cooled to under 94C with a compressed air blast every hour during each working day. The time lost during the cooling and re-heating to within 5C of the desired temperature varied from 10 to 15 minutes depending on the exposure temperature, burner rig used, combustion conditions, etc. The temperature was continually recorded, and measurements were available for each run.

Table V contains a listing of all the exposure runs. Three different rigs were used (nos 2,3 and 4). Due to different starting times, holidays, weekends and scheduling problems, each run had somewhat different effective times at temperature and number of thermal cycles as indicated.

It was believed that no significant differences in effects would be detected within the range of 800 to 1100 hours or after the number of cycles exceeded about 100. In identifying the exposures in the mechanical property results, only the net time is reported. As no two exposures at 982C had identical times, the net time will be sufficient to define the run number, total time and number of thermal cycles.

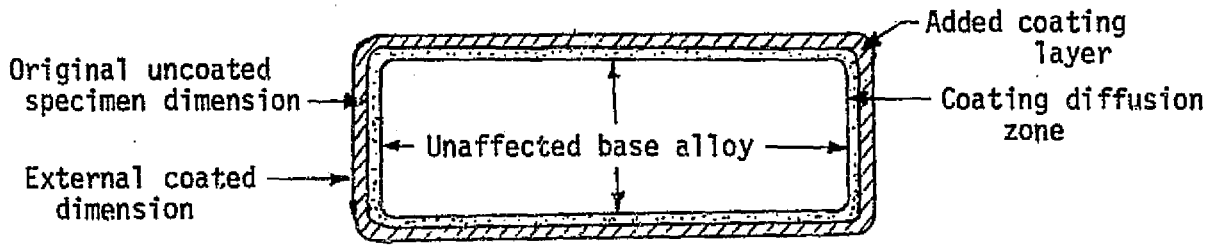
Only coated specimens were exposed. In no case was there ever any indication of coating distress or failure as shown by cracks, dark oxide spots, spalling, etc. The coatings became a dull, light gray color, and remained that way throughout the exposures. Coating integrity was confirmed metallographically. While diffusion occurred between the substrate and the coating, the coating outer layer itself was intact and exhibited slight surface oxidation (<0.0005cm). No measurable increase in thickness occurred.

Tensile Tests

Tensile tests were performed in air in accordance with ASTM procedures E8-66 and E21-66T at room temperature to 982C, as required, for standard size bars and thin section specimens. A strain rate of 0.005 mm/mm/min to yield and 0.05 mm/mm/min. to fracture was used. Ultimate and 0.2% yield strengths and elongations were measured (plus reduction of area for the standard size bars). All thin section and some of the standard size bars were tested by M.& P.T.L.Evendale, and the remainder of the standard size bars at Lynn.

The strengths of coated samples were calculated based on three different cross sectional areas:

1. Actual external dimensions, including coating.
2. Original uncoated specimen dimensions, ignoring changes caused by coating.
3. Unaffected base alloy dimensions, below all coating affected area (see sketch below)



Method 2 above is generally used for design purposes, and is the primary method discussed in the present work results. It implies no load carrying capacity in the added coating material, but includes the weakened diffusion zone as part of the metal. The first method assesses the full penalty of the coating to the specimen, while method 3 recognizes the poor strength of the entire coating and is most useful in evaluating the changes in properties of the base alloy itself. Strengths calculated by all three methods are reported in the Tables in a following section. Dimensions before and after coating were measured for each specimen. The unaffected base alloy dimensions were obtained by subtracting the total coating thickness, as determined metallographically on samples from the same run as the specimen or by the individual coating thickness measured by the Microderm, from the exterior measurements.

It was considered undesirable to make any kind of mark on the gage section of the thin specimens to provide for elongation measurements. Changes in length were measured at the inner center of the holes or at the edge of the shoulder. Elongation was calculated by assuming all the deformation took place in the flat uniform gage section. Frequently,

failure took place near the very end of the gage section, and this is noted in the property tables. Since the elongation is measured beyond that point, the values reported probably are affected only slightly.

Stress Rupture Tests

Stress rupture testing was performed in accordance with ASTM E139-66T procedures at 760C, 871C, 982C and 1093C. All specimens were directly dead weight loaded to attain the best possible alignment and accuracy of loading. Testing was performed at both M. & P.T.L. in Evendale and Lynn.

The test conditions selected for Rene 80 are:

760C, 565 MN/m^2

871C, 310 MN/m^2 and 262 MN/m^2

982C, 145 MN/m^2 and 117 MN/m^2

1093C, 34.5 MN/m^2

For Rene 120, the following were the test conditions:

760C, 634 MN/m^2

871C, 379 MN/m^2 and 310 MN/m^2

982C, 172 MN/m^2 and 145 MN/m^2

1093C, 55 MN/m^2

The stresses for coated specimens (unexposed and exposed) were based on the original uncoated specimen dimensions (method 2 above). Stress rupture lives were calculated for methods 1 and 3 as well by extrapolation along a line parallel to the master isothermal rupture curves for the test temperature, and are listed in the Tables in a following section. The lives in the Tables are all at the listed stress. Occasionally, tests of bare or coated specimens were run at stress slightly different than the desired stress. In order to permit comparisons, the lives of those specimens were extrapolated to the listed stress in the same manner: along a line

paralled to the master isothermal rupture curves. Such specimens are identified in the Tables.

Slight changes in stress levels affect rupture life appreciably. Misalignment, specimen defects, specimen eccentricity, etc. even within the limits required in the present work, have greater effects on thinner specimens and it is to be expected that greater variations in life will occur for the thinnest specimens.

Failures near the end of the gage length are indicated in the Tables, and have the same significance as discussed under tensile tests above. Some failures across the hole section occurred on the thinner specimens, and may be due to actual thinner material at that point than in the gage section, or to looser gripping than needed to maintain the specimen end flat. The lives of these pieces are less than the true life of a properly failed specimen, and elongations have little significance. Those hole failures are indicated in the Tables.

Mechanical Fatigue Tests

High cycle bending fatigue tests were run at room temperature on the 0.075cm thickness for Rene 120. Sonntag SF2 machines at a frequency of 1800 cycles per minutes were used to obtain 4 point S-N curves. Testing was performed by M&P.T.L in Lynn. The specimen was half a tensile/rupture specimen, Fig. 4, clamped at the wide section, with the narrow gage section oscillated. A load-deflection trial for each piece was made to determine the necessary deflection of the oscillating end of the specimen for the desired stress. External dimensions were used to calculate stresses for all tests.

Thermal Fatigue Tests

The same test used previously [1] was employed. The rounded "leading edges" of the 0.075cm thick castings were used, with 0.15cm flat Rene 80 sheets welded across the back for restraint. The thermal cycle was: heating time 10 seconds to 1093C, hold time 50 seconds, cooling time 20 seconds to under 204C. Specimens were inspected for cracks every several hundred cycles. Eight specimens (4 coated, 4 coated and exposed) were tested simultaneously for each alloy.

COMPLETE TEST DATA

Tensile Tests, Rene 80

The complete tensile test results for Heat B322 are given in Table VI and for Heat B353 in Table VII.

Heat B322 provided data for 0.075cm and 0.15cm thick specimens uncoated, coated, and coated and exposed at 982C and tested at room temperature, 871C and 982C. In addition, for the 0.075cm thickness only, coarse grained specimen (cast with no nucleation coating on the mold) data at room temperature and 871C, and coated and exposed at 899C specimen data at room temperature, 760C, 871C and 982C is included. All thin section specimens tested from this heat had as-cast surfaces. Specimen numbers preceded by a ? had some uncertainty in their proper identification, as explained in a previous section: the data they provide is completely usable. Several of the 0.15cm thick specimens had been originally mistakenly identified as Rene 120, and were heat treated and tested as such. Their results are included in Table VI for interest, but will not be used in furthur comparisons. It does appear that the Rene 120 heat treatment caused higher strengths at room temperature and lower strengths at 982C, with equivalent elongations at all temperatures.

Table VII, for Heat B353, includes the 0.038cm thickness specimen results as well as the effects of surface machining, coating, exposure at 982C, re-machining after exposure, recoating and re-exposing on the 0.075cm thickness. Some of the as-cast surface data was obtained from a different program and testing source (Metcut Research Associates, Inc.) which did not require specimen identification. These specimens are shown with no specimen numbers,

but their data is perfectly applicable and does appear equivalent to data from specimens of the present program where comparisons are available. Several of the thin specimens failed across the hole section: their true properties should be higher than the values shown, and they cannot be included readily in comparisons. It should be noted that the surface machined specimens (SM) are ~0.011cm thinner than as-cast specimens (AC), and that the SM specimens that have been exposed and SM again are ~0.025cm thinner than AC specimens, on the average.

The description and discussion of the results are contained in Volume I of the report.

Stress Rupture Tests, Rene 80

Tables VIII and IX include the complete stress rupture test results for the two heats, B322 and B353, respectively. Sufficient material from heat B322 was available for all the SM conditions, but the majority of the 0.038cm thick specimens were obtained from heat B353. There were a few 0.038cm pieces from heat B322 and these are listed with the other 0.038cm tests in Table IX. As mentioned in the Tensile Test section above,the 0.075cm thick specimens from heat B353 without numbers are from another program and test source and their results should be applicable here.

The incidence of failures through the holes was slightly higher for stress rupture than for tensile tests: generally on specimens whose original thickness, or thickness after multiple SM was under ~0.05/cm.

Dependence of stress rupture life on thickness is strong enough to warrant inclusion of exact thickness measurements in comparing the various test conditions, particularly after surface machining. Table X shows the average stress rupture lives for each condition, taken from the data in

Tables VIII and IX, together with the average elongation and thickness of the test specimens for each condition. Stress rupture life is considered to have a logarithmic distribution, therefore the average lives are calculated as a logarithmic average in most cases. Wherever very low life specimens occur together with longer lived specimens (less than 1/10 the life), or where specimens failed on loading (zero life), they are averaged linearly with the logarithmic average of the longer lived specimens of the same test condition.

Description and discussion of results are in Volume I.

Tensile Tests, Rene 120

All the tensile test results for the two Rene 120 heats, B325 and B415 are in Tables XI and XII respectively. Heat B325 data includes 0.075cm and 0.15cm thicknesses tested uncoated, coated and coated and exposed at 982C. Due to an error in identification, a group of uncoated specimens which had been treated as 0.15cm Rene 120 specimens, actually were Rene 80, as shown in Table VI. Further, the 0.075cm uncoated specimens meant to be tested at 982C were inadvertantly tested at 871C. Sufficient material from heat B325 was not available to replace all these specimens, and only single tests could be made for the conditions.

Heat B415, Table XII includes results of all the SM conditions of the 0.075cm thicknesses plus the few 0.038cm thick Rene 120 specimens available for tensile testing, in addition to the uncoated, coated and coated and exposed tests on the 0.075cm and 0.15cm thicknesses. Coarse, columnar grain specimens of the latter thickness were tested in duplicate, uncoated and coated, at room temperature and 871C only.

The standard size bar tests at 649C are for testing to the Rene 120 specification, and they met requirements.

Volume I contains the descriptions and discussion of the results.

Stress Rupture Tests, Rene 120

Stress rupture test results for heats B325 and B415 are included in Tables XIII and XIV, respectively. As with the tensile test results, heat B325 supplied data for uncoated, coated and coated and exposed specimens of 0.075cm and 0.15cm thicknesses, while heat B415 had these plus the SM conditions for the 0.075cm thicknesses, the few 0.038cm specimen tests, and some coarse columnar grained 0.15cm specimen tests. A few failures across the hole section occured, generally for the same conditions found in similar Rene 80 failures.

Note that the stresses used for the 871C and 982C tests were different for the two heats. The lower stresses selected for heat B415 were an attempt to obtain longer, more representative lives.

Table XV shows average stress rupture lives, elongation and specimen thicknesses calculated in the same manner as described previously for Rene 80. This permits making allowances for actual specimen thicknesses in comparing results, especially for the surface machined pieces.

Description and discussion of results are in Volume I.

Mechanical Fatigue Tests, Rene 120

Test results for reversed bending fatigue for both heats B325 and B415 are shown in Table XVI. Tests were run of the 0.075cm thickness as cast surface uncoated, coated and coated and exposed at 982C. One surface

machined specimen coated and exposed (two tests) was inadvertantly tested and its data is included also.

Failures usually occurred at the end of the uniform gage section, where the maximum bending moment/area ratio exists, except for a single specimen which failed up into the shoulder section (greater moment, but greater area).

Results are discussed in Volume I.

METALLURGICAL ANALYSIS

Metallographic Analysis, Rene 80

Metallographic inspections of virtually every specimen size and test condition were made. The more significant examples are included in Figures 5 through 13. The conditions and important features of each are listed below. Two etchants were used:

92-5-3 = 92% HCl, 5% H_2SO_4, 3% HNO_3

Carbide etch = 5% KOH, 5% $K_3FE(CN)_6$, 3 volts electrolytic

Figs. 5a-d: As-cast specimens, 0.075 cm and 0.15 cm thick, unetched and etched. The thinner specimen has more, and finer MC carbides; both have carbides uniformly dispersed. Eutectic γ' is present and is finer in the thinner specimen. Coring and relatively fine γ' is present in both. MC carbides and eutectic γ' are coarser in the standard size bars, and still finer in the 0.038 cm specimens (not shown).

Figs. 6a-d: Fully heat treated specimens (see section on Test Specimen Design and Preparation for description) 0.15 cm uncoated, and 0.075 cm Codep B-1 coated. The carbide etch shows fine recrystallized grains at the surface (Fig. 6a). Fig. 6b illustrates the de-alloyed surface layer caused by the heat treatment. Under the coating, there is an MC and $M_{23}C_6$- free zone, Fig. 6c. The internal structure, typical of all specimens has moderate size γ' uniformly distributed, with narrow grain boundaries, Fig. 6d. All eutectic γ' is gone.

Figs. 7a-h: Tensile test specimens. Tests at 871 and 982C of uncoated specimens usually had many small surface cracks (at recrystallized grain boundaries, Fig. 7a. The entire fracture of an 0.038 cm specimen, etched, Fig. 7b, shows the necking at the fracture, some of the small surface cracks, and the grain size relative to the thickness. Coated tensile specimens at R.T. had numerous coating cracks, Figs. 7c, e, f, g, while at 982C, the coating was

intact, Fig. 7h. The coating on the 0.038cm piece in a non-cracked area is normal (the added layer is attacked by the etchant, but the finger-like nature of the diffusion zone is clear), Fig. 7d. Unetched, Figs 7c,e, the cracks seem to go below the diffusion zone, whereas they really stop when the sound substrate is reached, Fig. 7f. The latter picture indicates that where a coating crack lines up at a grain boundary, it may continue to propagate. The jagged fractures indicate both transgranular and intergranular pathways.

Figs.8a-i: Stress rupture test specimens, uncoated. The nature, and amount of oxidation during testing for various times is illustrated in Figs. 8a-e. Etching reveals the heavy acicular sub-surface oxides formed at 982C (Fig. 8c), while at 1093C, the deep de-alloyed layer below the heavy surface scale is rather clear (Fig. 8d). The seriousness of oxidation during test for thin sections is shown by Fig. 8e for an 0.038cm specimen, where between 1/4 and 1/3 of the thickness has been consumed. The internal structural changes produced include thickening of the grain boundary $M_{23}C_6$ carbide network at 871 and 982C, Fig. 8f,g, visible by the carbide etch, and the broadening of the grain boundaries by formation of additional γ' or other phases, Fig. 8h. Testing at 1093C completely eliminates the $M_{23}C_6$ (solution temperature ~1065 C), and coarsens the γ' and the grain boundaries, Fig. 8i. Fractures were generally jagged as were the tensile tests.

Figs.9a-f: Stress rupture test specimens, coated. Complete protection against oxidation is afforded by the coating, Figs. 9a, b, d, e. The changes in the coating structures at the test temperatures are coarsening of the "fingers" in the diffusion zone and formation of acicular σ phase below the diffusion zone at 871 and 982C, Fig. 9a,b and

agglomeration of diffusion zone phases and transformation of coating NiAl to Ni_3Al at 1093C, Figs 9d,e,f. Tests at 760C produced many coating cracks, similar to Figs. 7c,e,f,g. A few persisted near the fracture at 871C. At 982C and 1093C, the coatings did not crack, and rupture voids formed below the coatings (Fig 9c) and did not penetrate the coating until final failure. The mode of failure was mixed up to 982C, and very difficult to determine at 1093C. The secondary internal cracks invariably were at grain boundaries.

Figs. 10a -c: Specimens exposed at 899C. Exposure for ~1000 hours at 899C, Figs. 10a,b,c produced about the same coating and internal changes noted in the much shorter times at 982C for the stress rupture specimens, Figs 9a,b,c. Although properties were affected, the fractures looked similar to unexposed samples.

Figs. 11a-e: Specimens exposed at 982C. The loss of coating diffusion zone fingers and the formation of acicular σ below is greater than occurs at 899C. After tensile testing at R.T., many coating cracks are present, and seem to follow the "needles" below the coating, Figs. 10a,b. Tensile tests at 871 and 982C do not cause coating cracks, Fig. 11c. The amount of unaffected metal in a thin coated specimen is reduced greatly, Figs. 11c,d. A major structural effect of the 982C exposure is the reduction of the amount of MC carbides: compare Figs. 11c,d to Figs. 8e,g. Carbon analysis on an exposed 0.038 cm specimen (Heat B353, no. 7188BA) revealed C had decreased to 0.12% from the initial 0.18% value. Grain boundaries are broadened, and additional γ' or other phases formed within them, Fig. 11b. Stress rupture testing at 1093C after the exposure further deteriorates the coating, coarsens the γ' and increases the grain boundary phases, particularly near the coating, Fig. 11e. Fracture modes are similar to unexposed specimens.

Figs. 12a-c: Coarse grained 0.075cm specimens (no mold nucleation coating). An aligned dendritic carbide structure exists, Fig. 12a, with a de-carbided layer near the surface, Fig. 12b, which is slightly wider than usual. A specimen, after stress rupture testing at 871C, shows the typical fine surface cracks at recrystallized grain boundaries, Fig. 12c. The coarse grain size is about average for these specimens, one to two grains across the section, although occasional areas have three grains across. The normal specimens of the same thickness have about four grains across the section, which represents about half the grain size of the coarse grained pieces. Fracture modes for these specimens were similar to the others.

Figs. 13a-g: Surface machined specimens. The surface and internal structures of surface machined specimens were the same as for the specimens with the as-cast surfaces, except the surface was smoother, and consequently the coating was more uniform. Fig. 13a shows the structure of a coated and exposed specimen, tensile tested at R.T. The agglomeration of the diffusion zone, transformation of some of the added layer, formation of sub-diffusion zone particles, production of coarse grain boundary $M_{23}C_6$ below and the coating crack are all visible. A similar specimen, stress rupture tested at 760C, etched to show the coarser γ', is included, Fig. 13b (the added coating layer is etched away). Re-surface machining and re-coating after exposure, produces a normal coating again, Fig. 13c, but the absence of the many MC carbides is clear. Carbon analyses on an exposed SM specimen (Heat B322, no. 47A) showed a drop to 0.13%, similar to the drop found for as-cast surface specimens, but after re-SM plus re-treatment and coating, C further decreased to 0.08% (spec. no. 15). A fine $M_{23}C_6$ grain boundary precipitate exists, as well as the coating crack after stress rupture testing at 760C. Etching reveals normal γ' size and distribution, Fig. 13d. After a second 982C exposure, the MC carbides are virtually completely gone, Fig. 13e. The coating deterioration and diffusion zone phases formed, Fig. 13F, are similar to their appearance after the first

exposure. Some $M_{23}C_6$ spherical particles are seen internally in Fig. 13f, and they are present in all specimens except those tested at 1093C, at which temperature they are dissolved. Fig. 13g shows the coarser γ' size, coarse grain boundary particles and diffusion zone products. Fractures of all SM specimens resembled those of the non-machined specimens tested at similar conditions.

Metallographic Analysis, Rene 120

As for Rene 80, nearly every specimen size and test condition was inspected metallographically. Representative structures are shown in Figures 14 through 21 , and are described below.

Figs. 14a-i: As cast specimens. The normal as-cast structure consists of MC carbides of different sizes, Figs. 14a,b, and eutectic γ' nodules and finer, distributed γ', Fig. 14c,in a standard size bar. In thinner sections, the same features are present, but carbides and γ' nodules are smaller, Figs. 14d -h, and some of the MC carbide tends to have a eutectic appearance, Figs. 14g,h. The occurrence of porosity in the Rene 120 castings was greater than in Rene 80, where almost none was found. The specimen in Fig. 14d was rejected by x-ray for porosity, while the specimen in Fig. 14e was the worst porosity accepted. Two sections from one of the 0.038 cm thick castings are illustrated in Fig. 14i. A longitudinal section near the gate had carbides almost as large as found in the the thick castings, but a cross section taken where the test specimens are machined had very small carbides.

Figs. 15a - g: Heat treated, uncoated tensile test samples. The heat treatment produced a very fine, discontinuous chain of particles in grain boundaries, Fig. 15a. Unlike Rene 80, eutectic γ' is not dissolved, Figs. 15b,c, even in the 0.038cm thickness, Fig. 15d although some diffusion seems to take place at the edges. Tensile fractures, as in Rene 80, tended to be

jagged and partly transgranular, Fig. 15e,f. The fracture frequently went through, or around the border of a γ' eutectic nodule, Fig.15f. As in Rene 80 again, the 871 and 982C tensile test specimens had fine surface cracks in recrystallized surface gain boundaries, Fig. 15g.

Figs. 16a -d: Heat treated, Codep B-1 coated tensile test samples. The coating produced on Rene 120 generally resembles that of Rene 80. The "fingered" diffusion zone structure is less clear, but otherwise the same, Fig. 16a. Etching shows the same internal structure as in uncoated Rene 120, and some additional diffusion area not visible unetched, Figs. 16b,c. The coating is heavily attacked by the etchant, as with Rene 80. Fractures were the same as in uncoated material, and R.T. tests produced much coating cracking. The coarse, columnar grained samples behaved the same way as the normal samples, in spite of their very large grain size, Fig. 16d. In many areas, a single grain spanned the thickness.

Figs. 17a - g: Uncoated stress rupture test specimens. The oxidation attack during testing is illustrated in Figs. 17a -e. The attack is less than found in Rene 80, and does leave a de-alloyed surface layer. The internal structural changes produced by the testing include an increase in the grain boundary particles, Fig. 17f (compare to Fib. 15a) and a great growth in the γ' size at the 1093C test, Fig. 17g (compare to Fig. 15c). Fractures up to 871C were usually mixed; at higher temperatures, the mode was difficult to distinguish.

Figs. 18a-d: Coated Rene 80 stress rupture test specimens. With increasing test temperature, the coating diffusion zone tended to agglomerate, and form acicular precipitates below, Figs. 18a-c. The γ' size increased and coarser grain boundary γ' formed near the coating, Fig. 18d. Coating cracks were present in the 760C tests, and rarely at 871C. No cracks were found in

the 982 and 1093C tests. Fractures were like the uncoated samples.

Figs. 19a-e: Coated Rene 120 and exposed at 982C specimens. The exposure coarsened the grain boundary carbides and γ', Figs. 19a,c,d. The diffusion zone of the coating was agglomerated somewhat, large acicular and needles were produced under the diffusion zone, and some transformation of the added coating layer occurred, Figs. 19b,c. These effects were further increased in the rupture test at 1093C, Fig. 19e. The number of σ needles is decreased in the latter specimen, while the ones that are present are longer. In Rene 80, the 1093C test eliminated the needles. Some fine acicular particles were occasionally formed in the interior of a piece, Fig. 19d. Fractures resembled the unexposed fractures.

Figs. 20a -f: Surface machined specimens. As with Rene 80, internal and surfaces were similar to as-cast specimens, except for the smoother surface (and coating). The normal internal structure is shown in Fig. 20a. After exposure, the γ' was coarsened, Fig. 20b. Re-surface machining after exposure, and re-coating produced a normal coating and internal structure, Fig. 20c,d; however, it can be seen that the amount of MC carbides has decreased while the grain boundary particles are still produced. The re-exposure produced the same structural effects as the original exposure, Figs. 20e, f. Due to the reduced thickness, the acicular phases are present throughout the sample. The MC carbide may be further reduced, while the grain boundary particles are present as before. Fractures of all surface machined specimens were similar to corresponding as cast specimens.

Figs. 21a -d: Fatigue test samples. The R.T. high cycle fatigue fractures were typical transgranular, usually along a specific crystallographic plane,

Figs. 21a-c, for the uncoated and coated specimens. After exposure at 982C, the fracture resembled a tensile fracture, Fig. 21d. The coating had cracks near the primary failure, Figs. 21c,d.

X-Ray Diffraction Analyses

X ray diffraction patterns were run on the exterior surfaces of various Rene 80 and Rene 120 specimens to verify the coating structures and follow the changes produced by exposure or stress rupture tests. The complete results are in Table XVII.

All specimens were run at identical settings on the X-ray equipment; the intensities for the three strongest lines of the major phases are listed and the relative intensities should indicate the relative amounts of each phase. The NiAl is the added layer compound, with some intentionally entrapped αAl_2O_3 particles. The added layer is thick enough to prevent detection of the diffusion zone or matrix phases. The appearance of γ or γ' in the pattern indicates that some of the coating has transformed. The $NiAl_2O_3$ spinel is the normal oxidation product of the coating.

With increasing temperature, or with increasing time at a fixed temperature, the amount of NiAl decreases, and the amount of γ-γ' increases for both alloys. The lattice parameter of the NiAl decreases, and the parameter of the γ-γ' is lower after 1093C exposure than after 982C. The γ-γ' parameter measured after exposure is not the parameter of the base alloy for Rene 80, but is close for Rene 120. The structure and behavior of the coating on Rene 120 is very similar to that on Rene 80.

Results are discussed in Volume I.

Coating Composition Variation, Rene 80

Electron microprobe analyses were run on metallographically mounted cross sections of coatings for the following conditions:

Heat B322	0.15 cm	as-coated
	"	exposed 993 hrs at 982C
	0.075 cm	as-coated
	"	exposed 997 hrs at 899C
	"	" 1013 " " 982C
	"	SM, as-coated
	"	" exposed 1019 hrs at 982C
	"	" " " " " " , re-SM, re-coated
	"	as above + re-exposed 1001 hrs at 982C
Heat B353	0.038 cm	as-coated
	"	exposed 1001 hrs at 982C
	0.075 cm	as-coated
	"	SM, as-coated

Scans from the base alloy through the coatings were run for all the major elements: Al, Ti, Cr, Co, Mo, W and Ni. The three most important constituents (in addition to Ni) are Al, Cr and Ti. Results for these three elements are plotted in weight percent as a function of the distance from the visible added layer-diffusion zone interface in Figs. 22-24 for the first 5 specimens listed above; in Figs. 25-27 for the next 4, and in Figs. 28-30 for the last 4. The compositions are "matrix" values, and do not show the Cr-W-Mo rich particles (σ phase) and Ti-Mo-W rich particles (MC) in the diffusion zone or the Al rich particles (αAl_2O_3) in the added layer.

Compositions for all three thicknesses, as coated, were normal and show only slight differences in total coating thickness (several coating runs are represented). Al peak levels are around 30% in the added layer, with Cr from 1 to 2% and Ti decreasing to near zero approaching the outer edge. Exposure at 899C, 997 hours, dropped peak Al content to 21% and diffused Al inwards for 20 to 30 microns beyond the original diffusion zone. As Al went down in the added layer, Cr and Ti (and Co and Ni not shown) increased, while Cr and Al were lowered in the diffusion zone. Exposure at 982C caused the same changes to a greater degree, with peak Al levels dropping to 16-18%. SM had little effect on composition and the re-coating after the second SM produced essentially a "new" coating (thicker than before). The second exposure at 982C produced similar changes to the first exposure.

Coating Composition Variation, Rene 120

The same type of microprobe scans made for Rene 80 were used for Rene 120. The following conditions were examined:

Heat B325	0.15 cm	as-coated
	"	exposed 993 hrs, 982C
	0.075 cm	as-coated
	"	exposed 997 hrs, 982C
Heat B415	0.15 cm	as-coated
	"	exposed 1000 hrs, 982C

The results for Al, Cr and Ti for the Heat B322 specimens are Figs. 31-33, and for Heat B415 in Figs. 34-36. Coating compositions are similar to those found for Rene 80. Maximum Al in the added layer is about the same for all as-coated samples, 26-29%, which is slightly lower than in Rene 80. However, after 982C exposure, the Al dropped to 17-19%, which is slightly higher than produced by the same exposures for Rene 80. Cr and Ti showed similar variations in each alloy, and MC, σ phase and αAl_2O_3 particles were also similar.

CONCLUSIONS

Tensile Properties

Average property curves for Rene 80 and Rene 120 are presented as a function of temperature and section thickness. From them, the following general effects are noted:

1. There is little effect of section thickness on 0.2% yield strength. All thin sections have lower values than standard size bars, except at 871C. The beneficial effects of fine grain size of thin sections compared to standard size bars at the lower temperatures are offset by the geometry effect.
2. Ultimate tensile strengths increase with increasing thickness at all elevated temperatures. At. R.T. the 0.075 cm thickness has the highest value.
3. Elongations for 0.075 cm and thicker sections are equivalent at all temperatures; for 0.038 cm sections, elongations are lowest.
4. The aluminide coating lowers the yield and ultimate strengths up to 871C and is beneficial at 982C and above. The strength losses at lower temperatures are greater for thinner sections.
5. The effects of coating on elongation are slight for Rene 80. Rene 120 elongations were lowered at all temperatures.
6. Exposure at 899C lowers tensile properties of 0.075 cm Rene 80 up to 871C; there is no effect at higher temperatures. Exposure at 982C lowers properties of the thinnest sections (Rene 80 and 120) up to 982C. Thicker sections are less affected at R.T., and show losses up to 871C only.
7. Coarse grain Rene 80 (0.075 cm), bare or coated had higher yield strength than normal grain material and near equal or lower ultimate strengths at R.T. and 871C. Coarser grain Rene 120 (0.15 cm), bare or coated, had lower R.T. and higher 871C strengths. Elongation for both alloys was slightly lower at R.T. and higher at 871C for the coarse grain material.

8. Surface machining generally improves elongation at all temperatures. Strengths at R.T. and 871C are not affected much, and are improved for both alloys at 982C. Exposure at 982C produces similar effects in surface machined and as-cast samples.
9. Machining off the coating and diffusion zone after 982C exposure increases elongation, but because of the reduced thickness, results in generally lower strengths. When corrected for thickness, strengths are higher at 982C and nearly equivalent to pre-exposed values at lower temperatures.
10. Re-heat treating and coating after an initial ~1000 hours, 982C exposure and removal of coating/diffusion area generally increases elongation, but lowers strengths, except for Rene 80 at R.T. and 871C. Additional exposure lowers all properties.

Stress Rupture Properties

Larson-Miller parameter plots, and curves of average rupture life and elongation as a function of section thickness are presented. The general effects are as follows:

1. In all cases, coated or uncoated, rupture life decreases with decreasing thickness for both alloys.
2. Uncoated, loss is least at 760C and greatest at 871C to 982C. Losses of as much as 98% of standard bar life occur for the 0.038 cm section. The greatest loss for 0.075 cm samples is 87% for Rene 120 and 77% for Rene 80. The greatest loss for the 0.15 cm samples is 66% for Rene 120 and 48% for Rene 80.
3. Coating lowers rupture lives up to 982C for all thicknesses of both alloys with greatest losses at lower temperatures and with little or no loss for the 0.075 cm and 0.15 cm thicknesses at 1093C. Maximum losses for 0.075 cm sections are 89% for Rene 80 and 93% for Rene 120.

4. Rupture elongation is generally equivalent for 0.075 cm and thicker samples of both alloys. The 0.038 cm samples are always lower. Coating lowers elongation only at 760C and 871C.
5. Exposure for ~1000 hours at 899C for 0.075 cm Rene 80 has little effect on life. Exposure at 982C lowers life up to 982C, with greater losses at lower temperatures for both alloys. There is little effect at 1093C for the thicker samples. Maximum losses are 99% for 0.038 cm section; 97% for Rene 80 and 98% for Rene 120 0.075 cm sections. For Rene 120 at the lowest temperatures, the 0.15 cm samples lost more life than did the 0.075 cm samples.
6. Exposure at 899C for Rene 80 does not affect elongation. Exposure at 982C lowers elongations for Rene 80 at 760C for all thicknesses and at 871C for the thinner specimens only. The exposure affects Rene 120 elongation to a lesser extent.
7. Coarse grain specimens of both alloys, uncoated or coated have lower rupture lives at 871C and higher lives at 1093C than normal grained specimens.
8. Surface machining of 0.075 cm specimens lowers rupture life at 760C and 871C, but not at higher temperatures. Elongations are generally improved. Coating lowers lives and elongations in most cases up to 982C; not at 1093C, as with as-cast surface specimens. Exposure at 982C of surface machined, coated specimens has similar effects as on as-cast surface specimens.
9. Removing the coating and diffusing zone after exposure results in lowering rupture life, in part because of the reduction in thickness. Correcting for thickness still leaves losses in most cases, especially at 760C. Re-treating and coating generally further lowers life. Re-exposure again drops life in most cases.

Thermal Fatigue

The cycle used on Rene 80 and Rene 120 did not cause failure in 4000 cycles with coated and coated/982C exposed specimens.

Mechanical High Cycle Fatigue

Uncoated, coated, and coated/exposed 982C Rene 120 specimens 0.075 cm thick have 10^7 cycle reversed bending fatigue strengths of 269 to 286 MN/m^2. These values are lower than Rene 80, but do not change as Rene 80 does, due to the coating or exposure.

Microstructures

1. Rene 80 contains eutectic γ' nodules, MC carbides and fine γ' as-cast. Heat treatment eliminates the eutectic γ', makes the dispersion of fine γ' more uniform and precipitates a small amount of fine $M_{23}C_6$ at grain boundaries. A fine de-alloyed band, and some MC carbide depletion within 0.002 cm of the surface may occur. A fine recrystallized grain region is formed usually at the surface.
2. Exposures at 899C and 982C coarsen the γ' and produce more $M_{23}C_6$ at grain boundaries at the expense of the MC.
3. Surface machining after initial heat treatment can remove the de-alloyed band, the MC depleted layer and the fine recrystallized grains.
4. Rene 120 contains eutectic γ' nodules, MC and fine γ' as-cast. Unlike Rene 80, the eutectic γ' is not eliminated by heat treatment. The grain boundary particles are of different composition than in Rene 80. The surface of Rene 120 resembles Rene 80, and the effects of exposure are similar.

5. Codep B-1 coating on both alloys forms a uniform "added" layer consisting of αAl_2O_3 particles embedded in an NiAl structure having some Ti, Cr, etc. from the matrix. A "diffusion" zone of equal thickness is formed and consists of finger-like particles of σ with NiAl, MC and matrix. Normal Al content of added layer is near 30%.
6. Exposures, and tests at high temperatures, agglomera e the diffusion zone fingers, grow further σ needles into the substrate, diffuse additional Al into grain boundaries and lower Al content of the added layer to 21% after ~1000 hours at 899C and ~17% after ~1000 hours at 982C. When Al content falls below ~20%, some of the NiAl starts transforming to Ni_3Al. The changes in the coating on Rene 120 appear to take place at a slightly lower rate than in Rene 80.
7. Removal of exposed coating, re-heat treatment and re-coating produces a like-new coating, but with additional MC depletion in the base alloy. Re-exposures after initial exposure plus re-coating produce similar changes to the first exposure. However, the continual decrease in MC may almost eliminate MC in a thin section after the multiple exposures.
8. For all test conditions, tensile and rupture fractures are generally intergranular, with occasional transgranular paths up to 982C.
9. Surface attack during stress rupture testing of uncoated material produces a uniform general oxidation with many fine internal oxides and an alloy depleted layer. Attack is less on Rene 120 than on Rene 80, and at 1093C, less oxide penetration occurs (greater surface scale). No attack is visible on coated specimens during test or exposure.

REFERENCES

1. Kaufman, M., "Examination of the Influence of Coatings on Thin Superalloy Sections", NASA CR-121115, August 1972.

2. Woodyatt, R.L., C.T. Sims and H.J. Beattie, Jr., "Prediction of Sigma-Type Phase Occurrence from Composition in Austenitic Superalloys", Trans. Met. Soc. AIME 236, 1966.

Table I Casting Pour Numbers, Thin Section Rene 80 and Rene 120

Specimen Thickness cm (inch)	Rene 80		Rene 120	
	Heat B322	Heat B353	Heat B325	Heat B415
0.038 (0.015)	Trial cast only	7070, 1, 2 7081 to 7094 7096, 7 21103 to 21107*	-	Trial cast only
0.075 (0.030)	7616, 7 7619 to 7622 7401 4335, 6 5982 to 5989** 8467***	4540 to 4544	8576 to 8582 4337	1374 to 1377 2771 to 2774 2776 to 2780 6252 7658, 9 29353, 4
0.15 (0.060)	7534, 5 7537 to 7539	-	8235 to 8237 8240, 1	2764 to 2769 6159, 6251 6401 7660, 1

* Identification numbers 65-113 in report.

** " " 2-122 " "

*** No nucleation coating on mold

Table II Chemical Analyses of Rene 80

Element	Specification Requirement	Heat B322				Heat B353
		Master Heat	Std. Bar 0.64 cm dia	0.15 cm Spec. 7536A2	0.075 cm Spec. 7617D2	Master Heat
Co	9.00 - 10.00	9.73	9.60	9.75	9.70	9.64
Cr	13.70 - 14.30	13.98	13.82	13.79	13.98	14.15
Al	2.80 - 3.20	3.00	3.05	2.89	2.85	2.95
Ti	4.80 - 5.20	5.18	5.04	4.83	4.93	4.88
Mo	3.70 - 4.30	3.80	3.86	3.99	3.84	3.78
W	3.70 - 4.30	4.00	3.90	4.01	3.80	4.05
Mo + W	7.70 Min.	7.80	7.76	8.00	7.64	7.83
B	0.010 - 0.020	0.014	0.021	0.011	0.011	0.019
C	0.15 - 0.19	0.156	0.169	0.153	0.167	0.18
Zr	0.02 - 0.10	0.04	0.032	0.020	0.023	0.04
Mn	0.20 Max.	0.1	-	-	-	0.1
Si	0.20 Max.	0.11	0.05	0.05	0.05	0.06
S	0.015 Max.	0.004	-	-	-	0.003
Fe	0.20 Max.	0.18	0.22	0.18	0.18	0.20
Cu	-	-	0.030	0.015	0.027	-
Ni	Remainder	Rem.	Rem.	Rem.	Rem.	Rem.
N_{v3}	2.32	2.16	-	-	-	2.25

All analyses in weight percent N_{v3} see Ref. 2.

Table III Chemical Analyses of Rene 120

Element	Specification Requirement	Heat B325				Heat B415
		Master Heat	Std Bar 0.64 cm dia	0.15 cm Spec. B38240	0.075 cm Spec. C38576	Master Heat
Co	9.50 - 10.50	9.95	9.96	9.89	9.93	9.70
Cr	8.60 - 9.40	9.15	9.05*	9.05*	9.05*	8.95
Al	4.10 - 4.50	4.12	4.32*	4.10*	4.10*	4.35
Ti	3.80 - 4.20	4.06	3.99	3.99	3.99	3.97
Al + Ti	8.10 Min.	8.18	8.42	8.09	8.08	8.32
Mo	1.60 - 2.40	1.72	1.83	1.83	1.85	2.04
W	6.60 - 7.40	6.78	6.75*	6.80*	6.80*	6.90
Mo + W	8.50 Min.	8.50	8.58	8.63	8.65	8.94
Ta	3.60 - 4.00	3.75	3.82	3.82	3.85	3.60
B	0.010 - -.020	0.017	0.013	0.013	0.013	0.018
C	0.15 - 0.20	0.193	0.180	0.185	0.180	0.19
Zr	0.05 - 0.10	0.07	0.06	0.06	0.07	0.10
Mn	0.10 Max.	<0.05	-	-	-	<0.1
Si	0.10 Max.	<0.10	-	-	-	<0.1
S	0.015 Max.	0.005	-	-	-	0.002
Fe	0.20 Max.	0.13	-	-	-	0.14
Cb	0.10 Max.	<0.05	-	-	-	<0.1
Cu	"	0.08	-	-	-	0.07
V	"	<0.01	-	-	-	<0.1
Hf	"	<0.03	-	-	-	<0.1
Ni	Remainder	Rem.	Rem.	Rem.	Rem.	Rem.
N_{v3}	2.30 Max.	2.17	-	-	-	2.29

* By X-ray fluorescence analysis.

All analyses in weight percent.

Table IV Surface Finish of Thin Section Castings

Alloy	Thickness cm (inch)	Spec. No.	Surface Finish, rms microinch	
			outer side	cored side
Rene 80	0.075 (0.030)	7620 D3	70	80
	"	7622 A2	65	70
	0.15 (0.060)	7537 D4	75	75
	"	7538 D2	80	90
	0.075 (0.030)	7401 A3*	70	-
	"	7	85	65
	"	9	85	70
Rene 120	0.075 (0.030)	B1 8581	70	80
	"	C2 8579	65	70
	0.15 (0.060)	A4 8237	65	65
	"	A2 8241	65	65
	0.075 (0.030)	A3 8577*	65	-
	"	2	95	70
	"	5	95	70

* Round "leading edge" section

Measured with Brush Surfindicator, model BL110

Table V Burner Rig Exposure Runs

Run No.	Temp. °C (°F)	Total Time, hrs.	No. of Cycles	Lost Time per Cycle min.*	Net Time hrs**	Alloys in Exposure
2-37	899 (1650)	1045.0	240	12	997	Rene 80, Heat B322
2-47	982 (1800)	1034.0	130	15	1001	Rene 80, Heat B353
2-48	" "	878.3	105	12	857	Rene 80, Heat B353 Rene 120, Heat B415
2-48A	" "	842.8	104	12	822	Rene 120, Heat B415
3-334	" "	1061.3	201	12	1021	Rene 80. Heat B322
3-335	" "	1030.3	201	10	997	Rene 120, Heat B325
3-344-1	" "	908.4	112	12	886	Rene 80, Heat B353
3-344-2	" "	1025.4	127	12	1000	Rene 80, Heat B353 Rene 120, Heat B415
3-44-3	" "	1066.3	132	12	1040	Rene 120, Heat B415
3-345	" "	926.8	104	12	906	Rene 120, Heat B415
3-346	" "	1039.6	130	12	1014	Rene 120, Heat B415
4-15	" "	1057.0	218	12	1013	Rene 80, Heat B322
4-16	" "	1029.5	220	10	993	Rene 120, Heat B325
4-18	" "	1069.1	200	15	1019	Rene 80, Heat B322

* Lost time includes cooling time during thermal cycling, and heating time to withing 5C (9F) of nominal exposure temperature.

** Rounded off to nearest hour.

Table VI Tensile Test Results: Rene 80 Heat B322

A. Test at Room Temperature

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	-	800 (116.1)	-	-	1038 (150.7)	-	7.0*	7.0
			-	-	817 (118.6)	-	-	1010 (146.7)	-	7.0	6.3
	SM-C	"	-	801 (116.2)	808 (117.2)	825 (119.6)	989 (143.5)	998 (144.7)	1018 (147.7)	5.0*	3.9*
0.075 (0.030)	AC-U	"	7621B2A	-	881 (127.8)	-	-	1182 (171.5)	-	3.9	-
	AC-U CG	"	8467B3A	-	871 (126.3)	-	-	1047 (151.9)	-	8.7	-
			8467A2A	-	897 (130.1)	-	-	1001 (145.2)	-	5.5	-
	AC-C	"	?7621D3B	725 (105.2)	754 (109.3)	848 (123.0)	965 (140.0)	1002 (145.3)	1129 (163.7)	8.2	-
			7619B1A	728 (105.4)	756 (109.6)	839 (121.7)	933 (135.3)	968 (140.4)	1075 (155.9)	6.0	-
			?7620C1A	746 (108.2)	773 (112.1)	854 (123.9)	994 (144.2)	1030 (149.4)	1139 (165.2)	8.5	-
			?7617A4B	749 (108.7)	789 (114.5)	857 (124.3)	953 (138.2)	1004 (145.6)	1089 (158.0)	6.5	-
	AC-C CG	"	8467B4A	852 (123.5)	900 (130.6)	969 (140.6)	960 (139.2)	1015 (147.2)	1093 (158.5)	5.1	-
			8467C2A	852 (123.5)	904 (131.1)	963 (139.7)	981 (142.3)	1042 (151.1)	1109 (160.9)	6.5	-
	AC-C	997 §	7616B3A	Erratic test record - Brittle failure						-	-
			7620C3A	605 (87.8)	626 (91.0)	690 (100.1)	605 (87.8)	626 (91.0)	690 (100.1)	1.0	-
	"	993§§	?7620A1B	601 (87.2)	622 (90.3)	696 (100.9)	674 (97.7)	700 (101.4)	780 (113.0)	4.5	-
			?7622B2A	615 (89.3)	650 (94.3)	721 (104.5)	637 (92.4)	673 (97.6)	747 (108.1)	3.0	-
			7622B2B	662 (96.0)	687 (99.6)	768 (111.3)	662 (96.0)	687 (99.6)	768 (111.3)	2.5	-
			7621A2A	734 (106.3)	762 (110.4)	850 (123.2)	775 (112.3)	804 (116.6)	898 (130.2)	2.5	-
0.15 (0.060)	AC-U	None	?7537B3B	-	765 (111.0)	-	-	855 (124.0)	-	2.5	-
			7535D4B	-	772 (112.0)	-	-	899 (130.6)	-	5.0	-
			7534B4A	-	772 (112.0)	-	-	903 (131.0)	-	3.5	-
			?7539A3B	-	772 (112.0)	-	-	956 (138.8)	-	6.0	-
			4335A3 †	-	853 (123.7)	-	-	977 (141.7)	-	3.6*	-
			4335A1 †	-	881 (127.8)	-	-	1117 (167.0)	-	8.9*	-
	AC-C	"	7534A4A	734 (106.5)	757 (109.8)	794 (115.1)	903 (131.0)	932 (135.1)	976 (141.5)	5.5	-
			?7538D3B	739 (107.2)	755 (109.5)	805 (116.8)	958 (139.0)	978 (141.9)	1044 (151.4)	8.5*	-
			7535C1A	749 (108.6)	774 (112.1)	814 (118.0)	895 (129.8)	923 (133.9)	972 (141.0)	5.7	-
			7537B3A	769 (111.5)	783 (113.5)	823 (119.3)	929 (134.8)	946 (137.2)	994 (144.2)	5.2	-
	"	993§§	?7539C1A	626 (90.8)	639 (92.6)	669 (97.1)	676 (98.0)	690 (100.0)	725 (105.1)	2.6	-
			7539B4A	655 (94.9)	673 (97.6)	710 (102.9)	697 (101.0)	717 (104.0)	756 (109.7)	3.2	-
			?7537C4B	668 (96.8)	688 (99.7)	720 (104.3)	676 (98.0)	694 (100.7)	728 (105.6)	1.0	-
			?7539B4B	656 (95.3)	669 (97.1)	706 (102.4)	695 (100.8)	709 (102.8)	749 (108.7)	2.9	-

B. Test at 760C (1400F)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	-	689 (100.0)	-	-	1010 (146.7)	-	8.0*	14.4
			-	-	690 (100.2)	-	-	1008 (146.2)	-	10.0*	12.4
0.075 (0.030)	AC-C	997 §	?7621A1A	666 (96.7)	692 (100.5)	776 (112.7)	666 (96.7)	692 (100.5)	776 (112.7)	0.2*	-
			?7616C2A	666 (96.7)	692 (100.5)	763 (110.8)	705 (102.3)	732 (106.2)	807 (117.1)	1.0	-

C. Test at 871C (1600F)

Std Size	SM-U	None	-	-	464 (67.4)	-	-	736 (106.9)	-	12.0*	24.8
			-	-	470 (68.2)	-	-	734 (106.6)	-	10.0*	23.0
	SM-C	"	-	490 (71.0)	494 (71.6)	505 (73.2)	731 (106.0)	736 (106.9)	753 (109.2)	18.0	22.0
0.075 (0.030)	AC-U	"	7619C4B	-	526 (76.4)	-	-	708 (102.7)	-	7.0*	-
	AC-U CG	"	8467A4	-	464 (67.3)	-	-	588 (85.3)	-	12.5	-
			8467D1	-	543 (78.8)	-	-	718 (104.1)	-	9.5	-
	AC-C	"	?7620B1B	431 (62.5)	446 (64.8)	499 (72.4)	594 (86.2)	616 (89.4)	688 (99.8)	15.2	-
			7617A4A	447 (64.8)	474 (68.7)	521 (75.5)	618 (89.6)	655 (95.0)	720 (104.4)	8.0*	-
			?7621D4B	470 (68.2)	487 (70.6)	547 (79.3)	623 (90.3)	645 (93.5)	725 (105.1)	7.5*	-
			?7622A3A	-	-	-	663 (96.2)	687 (99.7)	756 (109.6)	8.0*	-
	AC-C CG	"	8467C4B	478 (69.4)	503 (73.0)	543 (78.7)	586 (85.0)	616 (89.4)	665 (96.4)	10.6	-
			8467B2A	481 (69.8)	508 (73.7)	550 79.8)	562 (81.5)	593 (86.0)	643 (93.2)	13.9	-
	AC-C	997 §	7616D1C	369 (53.6)	383 (55.6)	427 (62.0)	565 (82.0)	585 (85.0)	653 (94.8)	2.0*	-
			7619A4A	452 (65.6)	477 (69.2)	521 (75.5)	598 (86.8)	630 (91.5)	688 (99.8)	3.0	-
	"	101399	7619C1B	474 (68.8)	492 (71.4)	540 (78.3)	474 (68.8)	492 (71.4)	540 (78.3)	0.2*	-
			?7617C4A	518 (75.2)	549 (79.6)	601 (87.1)	518 (75.2)	549 (79.6)	601 (87.1)	0.4*	-
			?7616D4B	543 (78.7)	563 (81.6)	625 (90.7)	543 (78.7)	563 (81.6)	625 (90.7)	0.2*	-
			7622A2B	545 (79.0)	576 (83.5)	628 (91.1)	607 (88.0)	641 (93.0)	700 (101.5)	0.8*	-
0.15 (0.060)	AC-U	None	?7534D2B	-	480 (69.7)	-	-	670 (97.3)	-	14.5	-
			4335A2 †	-	485 (70.3)	-	-	659 (95.5)	-	11.4	-
			?7535C1B	-	491 (71.3)	-	-	650 (94.4)	-	18.0	-
			4335B2 †	-	502 (72.8)	-	-	679 (98.5)	-	15.0	-
			7539B1A	-	512 (74.4)	-	-	678 (98.4)	-	10.5*	-
			?7538A3A	-	529 (76.8)	-	-	699 (101.5)	-	13.5	-

C. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.15 (0.060)	AC-C	None	?7538D2A	..	-	-	607 (88.0)	621 (90.3)	659 (95.6)	17.5*	-
			7538B2C	427 (62.0)	436 (63.3)	461 (66.9)	612 (88.8)	626 (90.7)	661 (95.8)	22.8	-
			7534A4B	457 (66.3)	472 (68.4)	496 (72.0)	631 (91.5)	652 (94.5)	685 (99.3)	16.0	-
			7535C4B	472 (68.4)	484 (70.2)	510 (73.9)	651 (94.4)	668 (96.9)	703 (102.0)	10.5*	-
	"	1021§§	753BA1B	532 (77.2)	548 (79.5)	576 (83.6)	621 (90.2)	641 (92.9)	673 (97.7)	1.5	-
			7534D4A	540 (78.3)	551 (79.9(	586 (85.0)	595 (86.4)	607 (88.1)	646 (93.7)	1.8	-
			?7534C4A	572 (83.0)	587 (85.2)	617 (89.5)	590 (85.6)	606 (87.9)	636 (92.3)	1.2	-
			?7539A4B	622 (90.3)	640 (92.8)	670 (97.2)	662 (96.0)	680 (98.7)	712 (103.3)	2.0	-

D. Test at 982C (1800F)

Std Size	SM-U	None	-	-	288 (41.8)	-	-	462 (67.1)	-	13.0*	25.8
			-	-	332 (46.8)	-	-	473 (68.7)	-	16.0	26.5
	SM-C	"	-	254 (36.9)	256 (37.2)	262 (38.0)	432 (62.6)	435 (63.1)	445 (64.5)	5.0*	21.1
0.075 (0.030)	AC-C	"	7616A3A	248 (35.9)	262 (38.0)	285 (41.4)	331 (48.0)	350 (50.8)	381 (55.3)	6.7*	-
			?7617B2B	253 (36.7)	268 (38.9)	288 (41.8)	363 (52.6)	384 (55.7)	413 (59.9)	10.7	-
			?7620B4B	256 (37.2)	268 (38.9)	296 (43.0)	367 (53.2)	383 (55.6)	424 (61.5)	8.7*	-
			?7621C1A	290 (42.1)	301 (43.7)	341 (49.4)	408 (59.2)	424 (61.5)	478 (69.4)	9.1*	-
	"	997 §	7616D3A	249 (36.1)	257 (37.4)	283 (41.1)	326 (47.4)	338 (49.1)	372 (54.0)	15.0	-
			?7619C4A	266 (38.6)	276 (40.1)	311 (45.1)	346 (50.3)	360 (52.2)	405 (58.8)	13.2	-
	"	1013§§	7620C4B	259 (37.5)	272 (39.4)	294 (42.6)	321 (46.6)	337 (48.9)	365 (52.9)	10.5	-
			7616C1A	262 (38.0)	271 (39.3)	299 (43.3)	346 (50.2)	358 (51.9)	394 (57.2)	3.2*	-
			7619A1A	265 (38.5)	275 (39.9)	306 (44.4)	340 (49.3)	352 (51.1)	392 (56.8)	6.2*	-
			?7401A4B	283 (41.1)	292 (42.4)	322 (46.7)	339 (49.1)	350 (50.7)	384 (55.7)	4.0*	-

D. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.15 (0.060)	AC-U	None	4335A2 †	-	233 (33.8)	-	-	390 (56.6)	-	12.9	-
			7535A1B	-	257 (37.3)	-	-	401 (58.2)	-	13.0	-
			4335A4 †	-	267 (38.7)	-	-	375 (54.4)	-	13.8	-
			?7535B1A	-	271 (39.3)	-	-	381 (55.3)	-	17.0	-
			?7535B3B	-	271 (39.3)	-	-	397 (57.6)	-	17.5	-
			?7538D3A	-	280 (40.6)	-	-	400 (58.0)	-	16.3	-
	AC-C	"	?7538C1A	245 (35.6)	258 (37.4)	265 (38.4)	353 (51.2)	371 (53.8)	381 (55.2)	11.0	-
			7539B3A	263 (38.1)	276 (40.0)	285 (41.3)	367 (53.3)	385 (55.9)	397 (57.6)	11.0*	-
			7535D3A	265 (38.4)	273 (39.6)	286 (41.5)	375 (54.4)	387 (56.1)	405 (58.8)	11.7	-
			?7535A2B	273 (39.6)	279 (40.4)	296 (43.0)	361 (52.3)	368 (53.4)	392 (56.8)	11.0	-
	"	1021§§	7538D2B	specimen overheated in test fixture							-
			?7535B4A	235 (34.1)	242 (35.1)	253 (36.7)	367 (53.2)	377 (54.7)	393 (57.1)	11.5	-
			?7534C1A	251 (36.4)	257 (37.3)	271 (39.4)	365 (53.0)	374 (54.2)	395 (57.4)	14.5	-
			7538A1A	259 (37.6)	267 (38.7)	281 (40.8)	381 (55.2)	391 (56.8)	413 (59.9(	5.8	-

* Specimens failed at or near end of gage length.

† Specimens given Rene 120 heat treatment.
†† Specimen condition: AC = As cast, SM = Surface machined, U = Uncoated, C = Coated, CG = Coarse grained

(1) Strength based on external specimen dimensions including coating.
(2) " " " original specimen dimensions before coating.
(3) " " " unaffected remaining metal thickness (below coating additive layer and diffusion zone).

; Exposure temperature = 899C (1650F)
§§ " " = 982C (1800F)

Table VII Tensile Test Results: Rene 80 Heat B353

A. Test at Room Temperature

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	-	766 (111.0)	-	-	886 (128.5)	-	5.0	2.5
			-	-	767 (111.2)	-	-	934 (135.5)	-	8.0	6.5
	SM-C	"	-	788 (114.2)	796 (115.4)	811 (117.7)	897 (130.0)	906 (131.4)	922 (133.8)	5.0	3.0
			-	791 (114.7)	801 (116.1)	815 (118.3)	917 (133.0)	929 (134.8)	947 (137.3)	5.0	3.2
0.038 (0.015)	AC-U	"	100	-	744 (107.9)	-	-	816 (118.4)	-	5.9	-
			7182AB	-	757 (109.8)	-	-	757 (109.8)	-	1.5	-
			7072C	-	809†(117.3)	-	-	962†(139.3)	-	3.9†	-
			96	-	812 (117.7)	-	-	891 (129.2)	-	5.4	-
	AC-C	"	7070B	614 (89.0)	671 (97.3)	768 (111.4)	685 (99.3)	749 (108.7)	858 (124.4)	4.7	-
			95	652 (94.5)	723 (104.9)	977 (141.7)	652 (94.5)	723 (104.9)	977 (141.7)	1.3	-
			7188C	637 (92.4)	684 (99.2)	756 (109.7)	768 (111.4)	825 (119.7)	913 (132.4)	5.2*	-
			86	666 (96.6)	721 (104.5)	802 (116.3)	737 (106.9)	797 (115.6)	887 (128.7)	1.8	-
	"	1001	7071C	488 (70.8)	517 (75.0)	611 (88.6)	488 (70.8)	517 (75.0)	611 (88.6	0.7*	-
			7189BB	510 (74.0)	548 (79.5)	618 (89.7)	523 (75.9)	562 (81.5)	634 (92.0)	0.9	-
			7072AA	596 (86.5)	632 (91.7)	747 (108.3)	596 (86.5)	632 (91.7)	747 (108.3)	1.0*	-
			7185AB	610 (88.5)	642 (93.1)	740 (107.4)	616 (89.3)	647 (93.9)	747 (108.3)	1.9	-
0.075 (0.030)	AC-U	None	-	-	765 (111.0)	-	-	1041 (151.0)	-	8.8	-
			-	-	793 (115.0)	-	-	1130 (164.0)	-	11.9	-
	AC-C	"	4543D1B	743 (107.5)	777 (112.8)	855 (124.0)	948 (137.5)	992 (143.9)	1092 (158.2)	9.0*	-
			-	753 (109.2)	789 (114.3)	855 (124.0)	996 (144.6)	1042 (151.2)	1130 (164.0)	8.3	-
			-	765 (111.0)	801 (116.2)	869 (126.0)	966 (140.2)	1011 (146.8)	1097 (159.0)	7.8	-
			4540A1B	783 (113.5)	812 (117.8)	903 (131.0)	952 (138.0)	988 (143.2)	1098 (159.1)	8.2*	-
	SM-U	"	4540A4B	-	761 (110.3)	-	-	1117 (161.8)	-	15.7	-
			4541C1B	-	775 (112.3)	-	-	932 (135.1)	-	5.1*	-
			4543A3B	-	792 (114.9)	-	-	1030 (149.3)	-	8.8*	-
			4541 B1	-	808 (117.2)	-	-	1087 (157.5)	-	10.0	-

A. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C	None	4541C4A	675 (97.9)	719 (104.2)	789 (114.3)	831 (120.4)	884 (128.2)	969 (140.5)	4.9*	-
			4541A4	680 (98.6)	724 (105.0)	795 (115.2)	899 (130.3)	958 (138.9)	1049 (152.0)	9.7	-
			4544D2B	690 (100.0)	733 (106.2)	802 (116.3)	811 (117.5)	862 (124.9)	942 (136.6)	4.7	-
			4540B4B	719 (104.2)	753 (109.2)	848 (123.0)	899 (130.3)	942 (136.7)	1060 (153.6)	9.4	-
	"	1001	4544A2B	622 (90.2)	656 (95.1)	727 (105.5)	648 (94.0)	683 (99.1)	758 (110.0)	1.7*	-
			4543C1	642 (93.1)	678 (98.3)	729 (105.8)	683 (99.0)	721 (104.6)	776 (112.5)	6.7	-
			4544B3A	674 (97.7)	719 (104.3)	785 (113.9)	698 (101.3)	746 (108.2)	814 (118.1)	5.4	-
			4540C2B	692 (100.4)	734 (106.5)	802 (116.3)	743 (107.8)	789 (114.4)	861 (124.9)	5.5	-
	SM-C-E-SM	"	4544B1	-	681 (98.8)	-	-	741 (107.5)	-	4.0	-
			4541D2B	-	743 (107.8)	-	-	858 (124.5)	-	6.0	-
			4540B2B	-	771 (111.8)	-	-	798 (115.7)	-	3.7	-
			4541A3B	-	798 (115.7)	-	-	827 (120.0)	-	4.5	-
	SM-C-E-SM-C	1001	4540A4A	639 (92.7)	683 (99.1)	816 (118.3)	639 (92.7)	683 (99.1)	816 (118.3)	1.3	-
		"	4541D1A	667 (96.7)	727 (105.4)	829 (120.3)	716 (103.8)	780 (113.1)	891 (129.2)	1.8	-
		886	4544A3A	668 (96.9)	719 (104.3)	803 (116.5)	725 (105.2)	780 (113.2)	872 (126.5)	2.1	-
		"	4544B4	678 (98.3)	736 (106.7)	834 (121.0)	741 (107.5)	805 (116.7)	912 (132.3)	2.8	-
	SM-C-E-SM-C-E	1001/857	4540B4A	424 (61.5)	481 (69.7)	538 (78.0)	424 (61.5)	481 (69.7)	538 (78.0)	0.6*	-
		"	4541B3A	481 (69.8)	507 (73.6)	590 (85.5)	481 (69.8)	507 (73.6)	590 (85.5)	0.5*	-
		"	4541C2A	541 (78.4)	587 (85.1)	676 (98.1)	541 (78.4)	587 (85.1)	676 (98.1)	0.6*	-
		886/857	4543A2	567 (82.2)	612 (88.7)	687 (99.7)	567 (82.2)	612 (88.7)	687 (99.7)	0.8*	-

B. Test at 760C (1400F)

0.075 (0.030)	AC-U	None	-	-	649 (94.2)	-	-	951 (138.0)	-	6.5	-
	AC-C	"	-	633 (91.8)	660 (95.8)	717 (104.0)	900 (30.4)	942 (136.6)	1020 (148.0)	5.0	-
			-	661 (96.0)	693 (100.6)	751 (109.0)	918 (133.1)	960 (139.2)	1041 (151.0)	3.0	-

C. Test at 871C (1600F)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	-	425 (61.6)	-	-	629 (91.2)	-	5.7	-
			-	-	462 (67.0)	-	-	653 (94.6)	-	13.0	17.3
			-	-	497 (72.1)	-	-	681 (98.7)	-	12.0	15.8
			-	-	519 (75.3)	-	-	696 (101.0)	-	12.0	19.7
			-	-	534 (77.4)	-	-	696 (101.0)	-	12.5	18.9
	SM-C	"	-	446 (64.6)	451 (65.4)	460 (66.7)	639 (92.6)	646 (93.7)	659 (95.6)	13.0	14.1
			-	449 (65.1)	455 (66.0)	462 (67.1)	671 (97.4)	681 (98.7)	692 (100.4)	22.0	29.0
0.038 (0.015)	AC-U	"	7188AA	-	442†(64.2)	-	-	534†(77.4)	-	*	-
			89	-	536 (77.7)	-	-	614 (89.1)	-	4.8	-
			72	-	536 (77.7)	-	-	623 (90.4)	-	6.3	-
			111	-	548 (79.5)	-	-	635 (92.1)	-	5.8	
	AC-C	"	7182AA	341 (49.5)	359 (52.1)	416 (60.4)	342 (49.6)	360 (52.2)	419 (60.6)	0.9	-
			66	458 (66.4)	504 (73.1)	601 (87.1)	526 (76.3)	579 (84.0)	689 (100.0)	2.1*	-
			7196AA	479 (69.5)	507 (73.5)	593 (86.0)	564 (81.8)	596 (86.5)	698 (101.3)	1.6*	-
			101	485 (70.4)	511 (74.1)	585 (84.8)	565 (82.0)	595 (86.3)	681 (98.7)	6.7	-
	"	1001	7183AB	345 (50.0)	371 (53.8)	461 (66.8)	345 (50.0)	371 (53.8)	461 (66.8)	0.5	-
			7192BA	-	-	-	449†(65.1)	483†(70.1)	550 (79.7)	- †	-
			7071AB	461 (65.9)	487 (70.7)	571 (82.8)	461 (65.9)	487 (70.7)	571 (82.8)	0.4*	-
			7196B	492 (71.4)	518 (75.1)	597 (86.6)	492 (71.4)	518 (75.1)	597 (86.6)	0.8*	-
0.075 (0.030)	AC-U	None	-	-	440 (63.9)	-	-	672 (97.5)	-	10.0	-
			-	-	469 (68.0)	-	-	673 (97.6)	-	13.9	-
	AC-C	"	-	449 (65.1)	470 (68.2)	510 (74.0)	643 (93.3)	674 (97.7)	731 (106.0)	5.9	-
			4543C2	483 (70.0)	507 (73.5)	544 (78.8)	623 (90.4)	655 (94.9)	700 (101.6)	12.6*	-
			4541C2B	491 (71.2)	511 (74.1)	556 (80.6)	642 (93.2)	669 (97.0)	728 (105.6)	11.7	-
			-	493 (71.5)	516 (74.8)	559 (81.1)	614 (89.0)	642 (93.1)	696 (101.0)	2.9*	-
	SM-U	"	4544B2	-	471 (68.2)	-	-	632 (91.7)	-	19.2	-
			4543D4	-	478 (69.3)	-	-	636 (92.3)	-	13.1	-
			4540C3B	-	488 (70.8)	-	-	636 (91.4)	-	12.4	-
			4541A3A	-	517 (75.0)	-	-	630 (91.4)	-	17.1	-
	SM-C	"	4544B3B	-	-	-	574 (83.3)	610 (88.5)	667 (96.8)	5.0	-
			4541D3	451 (65.4)	470 (68.1)	517 (75.0)	584 (84.6)	607 (88.1)	670 (97.1)	7.6*	-
			4540C2A	452 (65.5)	480 (69.6)	525 (76.1)	578 (83.8)	614 (89.0)	671 (97.3)	8.7*	-
			4540B2A	455 (65.9)	485 (70.3)	524 (76.0)	590 (85.6)	630 (91.3)	681 (98.8)	4.2*	-

C. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C	1001	4544A4	338 (49.0)	368 (53.4)	393 (57.0)	338 (49.0)	368 (53.4)	393 (57.0)	0.6*	-
			4543D1A	449 (65.1)	480 (69.6)	519 (75.3)	449 (65.1)	480 (69.6)	519 (75.3)	0.8*	-
			4544C4B	523 (75.9)	553 (80.2)	596 (86.4)	565 (82.0)	598 (86.7)	644 (93.4)	1.2*	-
			4541D2A	637 (92.4)	674 (97.8)	742 (107.6)	656 (95.2)	695 (100.8)	764 (110.8)	1.3*	-
	SM-C-E-SM	"	4541B2A	-	448 (65.0)	-	-	479 (69.4)	-	0.8*	-
			4541A1	-	449 (65.1)	-	-	481 (69.8)	-	0.7	-
			4543D3	-	494 (71.7)	-	-	534 (77.5)	-	1.6	-
	SM-C-E-SM-C	886	4543B3	405 (58.8)	441 (65.0)	501 (71.8)	405 (58.8)	441 (65.0)	501 (71.8)	1.2*	-
		1001	4540D3B	454 (65.8)	498 (72.2)	575 (83.4)	552 (80.0)	605 (87.8)	700 (101.5)	2.0*	-
		"	4541C3A	467 (67.7)	510 (73.9)	584 (84.7)	488 (70.8)	533 (77.3)	611 (88.6)	1.6	-
		"	4540C1	553 (80.2)	604 (87.6)	692 (100.4)	574 (83.3)	627 (91.0)	718 (104.2)	1.2*	-
	SM-C-E-SM-C-E	1001/857	4540A3B	256 (37.2)	279 (40.5)	317 (46.0)	256 (37.2)	279 (40.5)	317 (46.0)	0.3*	-
		886/857	4544C2A	259 (37.5)	288 (41.7)	323 (46.9)	259 (37.5)	288 (41.7)	323 (46.9)	0.4*	-
		1001/857	4541A2B	279 (40.5)	297 (43.1)	348 (50.4)	279 (40.5)	297 (43.1)	348 (50.4)	0.4*	-
		" /857	4540D1	379 (55.0)	399 (57.9)	462 (67.0)	385 (55.8)	405 (58.8)	469 (68.0)	1.0*	-

D. Test at 982C (1800F)

Std Size	SM-U	None	-	-	216 (31.3)	-	-	369 (53.5)	-	18.0	32.8
			-	-	237 (34.4)	-	-	412 (59.8)	-	17.0	33.3
	SM-C	"	-	231 (33.5)	234 (33.9)	238 (34.5)	392 (56.9)	397 (57.5)	404 (58.6)	10.0	19.3
			-	289 (41.9)	292 (42.4)	298 (43.2)	388 (56.2)	392 (56.9)	400 (58.0)	10.0	21.7
0.038 (0.015)	AC-U	"	85	-	160 (23.3)	-	-	232 (33.7)	-	2.4	-
			93	-	207 (30.0)	-	-	279 (40.5)	-	8.0	-
			7183B	-	220 (31.9)	-	-	320 (46.4)	-	6.2	-
			81	-	234 (34.0)	-	-	300 (43.5)	-	5.8	-
	AC-C	"	7191AB	208 (30.2)	222 (32.2)	269 (39.0)	229 (33.3)	245 (35.5)	297 (43.0)	1.1*	-
			7072AB	212 (30.7)	222 (32.2)	264 (38.3)	264 (38.3)	277 (40.2)	330 (47.9)	2.1*	-
			71	214 (31.1)	230 (33.3)	276 (40.0)	230 (33.4)	247 (35.8)	296 (43.0)	1.7*	-
			105	236 (34.3)	251 (36.4)	292 (42.4)	327 (47.4)	346 (50.2)	403 (58.5)	5.8	-

D. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.038 (0.015)	AC-C	1001	7071GA	-	-	-	155 (22.5)	168 (24.4)	203 (29.5)	0.7*	-
			7188BA	172 (25.0)	182 (26.4)	214 (31.0)	179 (26.0)	190 (27.5)	222 (32.2)	1.1*	-
			7184B	207 (30.0)	219 (31.8)	261 (37.8)	208 (30.2)	225 (32.6)	268 (38.8)	1.3*	-
			7194AA	231 (33.5)	244 (35.4)	285 (41.4)	242 (35.1)	256 (37.1)	299 (43.4)	1.4*	-
0.075 (0.030)	AC-U	None	4540D2A	-	254 (36.9)	-	-	381 (55.2)	-	10.4	-
	AC-C	"	4540D2B	225 (32.7)	234 (33.9)	262 (38.0)	312 (45.2)	324 (47.0)	363 (52.6)	11.5	-
			4544C2B	242 (35.1)	253 (36.7)	275 (39.9)	332 (48.1)	347 (50.3)	378 (54.8)	7.6	-
	SM-U	"	4544A2A	-	245 (35.6)	-	-	350 (50.7)	-	11.3	-
			4541D1B	-	249 (36.2)	-	-	361 (52.3)	-	14.5	-
			4543C3A	-	256 (37.1)	-	-	341 (49.7)	-	11.8	-
			4540B3	-	262 (38.1)	-	-	369 (53.5)	-	16.2	-
	SM-C	"	4541B3B	232 (33.6)	246 (35.7)	269 (39.0)	308 (44.7)	327 (47.5)	358 (51.9)	9.6*	-
			4540A1A	236 (34.2)	250 (36.3)	274 (39.7)	322 (46.7)	342 (49.6)	374 (54.3)	7.5	-
			4540D3A	237 (34.3)	252 (36.5)	276 (40.0)	319 (46.2)	339 (49.2)	371 (53.9)	12.8*	-
			4544C4A	252 (36.5)	267 (38.8)	292 (42.4)	338 (49.0)	359 (52.1)	393 (56.9)	13.4	-
	"	886	4543B1	181 (26.2)	191 (27.7)	207 (30.0)	243 (35.3)	258 (37.4)	279 (40.4)	2.0*	-
			4543A1B	214 (31.0)	231 (33.5)	249 (36.1)	267 (38.7)	289 (41.9)	311 (45.1)	4.7	-
			4543D2B	217 (31.5)	228 (33.0)	250 (36.2)	343 (49.7)	359 (52.1)	394 (57.1)	3.4	-
	SM-C-E-SM	1001	4544A3B	-	221 (32.0)	-	-	299 (43.3)	-	2.6	-
			4541A2A	-	263 (38.2)	-	-	314 (45.6)	-	1.8*	-
			4541C1A	-	273 (39.6)	-	-	346 (50.2)	-	2.5	-
			4541B4B	-	276 (40.0)	-	-	316 (45.8)	-	1.9*	-
	SM-C-E-SM-C	886	4543D2A	178 (25.8)	203 (29.5)	225 (32.7)	213 (30.9)	243 (35.3)	270 (39.2)	2.7*	-
		1001	4540C4	193 (28.0)	209 (30.3)	240 (34.8)	208 (30.1)	224 (32.5)	258 (37.4)	1.2*	-
		"	4541B4A	230 (33.3)	245 (35.5)	279 (40.5)	268 (38.9)	286 (41.5)	326 (47.3)	1.9	-
		"	4540C3A	235 (34.1)	253 (36.7)	280 (40.6)	258 (37.4)	278 (40.3)	307 (44.5)	1.4*	-
	SM-C-E-SM-C-E	886/857	4543C3B	150 (21.8)	167 (24.2)	187 (27.1)	152 (22.0)	168 (24.4)	188 (27.3)	1.9*	-
		1001/857	4540A2	151 (21.9)	163 (23.7)	194 (28.2)	176 (25.5)	190 (27.6)	226 (32.8)	1.4*	-
		"	4541C4B	154 (22.3)	163 (23.6)	190 (27.6)	194 (28.1)	205 (29.7)	240 (34.8)	1.2*	-
		886/857	4544D4	183 (26.5)	192 (27.8)	218 (31.6)	195 (28.3)	205 (29.7)	233 (33.8)	1.9*	-

†† Specimen Condition: AC = As cast, SM = Surface machined: removed 0.05 to 0.07 mm (0.0025 inch) for initial SM on 0.075 cm specimens (each side); 0.12 to 0.13 mm (0.005 inch) for SM after exposure on 0.075 cm specimens (each side) and on radius of standard size bars, U = Uncoated, C = Coated, E = Exposed,

Exposure temperature = 982C (1800F)

* Specimens failed at or near end of gage length.
† " " in grip section. True life should be higher.

(1) Strength based on external specimen dimensions including coating.
(2) " " " original specimen dimensions before coating.
(3) " " " unaffected remaining metal thickness (below coating additive layer and diffusion zone).

Table VIII Stress Rupture Test Results: Rene 80 Heat B322

A. Test at 760C (1400F), 565 MN/m^2 (82,000 psi)(2)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	(1)	(3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	157.0	-	-	6.5*	17.2
			-	266.0	-	-	10.0	20.0
	AC-C	"	-	136.3	124	173	5.7	11.3
0.075 (0.030)	AC-U	"	?7622D1A	22.7	-	-	4.7	-
			?7617C3A	100.0	-	-	10.7	-
			7620A1A	105.0	-	-	10.2	-
			7616B1A	106.6	-	-	12.1	-
	AC-C	"	?7616A1B	3.2	2	10	2.3	-
			?7617B4A	8.2	5	28	3.3	-
			?7621C2A	20.3	14	51	4.1	-
			7620D3B	46.3	31	134	6.3	-
	"	997 §	?7617C3B	Failed on Loading			0.7	-
			7622D4B	34.6	22	100	5.6	-
	"	1013§§	7620A4B	Failed on Loading			0.1	-
			7621C3A	"	"	"	0.5	-
			7617B2A	0.5	0.2	1	0.2	-
			7616D3B	4.2	3	11	0.7	-
	SM-U	None	54A	1.6	-	-	2.3*	-
			122A	5.8	-	-	5.7	-
			106B	6.9	-	-	5.3	-
			45B	9.8	-	-	13.0	-
	SM-C	"	? 105A	Overtemperature in Test				-
			96B	3.0	2	13	2.0*	-
			4	6.3	4	24	2.9*	-
			? 72B	9.2	5	31	7.6	-
	"	1019§§	27	0.1	0.1	0.4	0.7*	-
			? 47A	0.1	0.1	0.5	0.1*	-
			105B	27.3	15	91	1.7	-
			82	45.2	25	152	4.9	-
	SM-C-E-SM	"	17B	0.1	-	-	1.0*	-
			6B	0.2 †	-	-	0.0*	-
			58	1.6	-	-	0.8	-
			88A	32.2 †	-	-	2.0*	-
	SM-C-E-SM-C	"	81	0.02	-	-	0.7	-
			40	0.1 †	0.05†	1†	0.6*	-
			15	0.1	0.05	0.4	0.8	-
			102B	0.2	0.1	1.2	0.5*	-
	SM-C-E-SM-C-E	1019/1001§§	46A	Failed on Loading			0.4*	-
			? 121	"	"	"	0.4	-
			90A	"	"	" †	-	-
			? 25	0.5†	0.3†	2†	-	-

A. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.15 (0.060)	AC-U	None	7535C3A	123.8	-	-	8.0	-
			7539C3A	148.7	-	-	7.0	-
			7537A2A	177.6	-	-	9.0*	-
			7538D1A	189.7	-	-	10.0*	-
	AC-C	"	7534B2B	53.7	40	98	5.6	-
			?7538A2B	61.4	44	105	6.7	-
			7535D1A	90.0	63	155	7.0	-
			7537C1A	92.5	66	157	7.7	-
	"	1021§§	7534A2A	† 0.3	-	-	1.0*	-
			?7537C3B	55.1	43	101	5.0	-
			?7538B3A	70.2	51	113	3.8	-
			7539D2A	71.7	57	111	3.3	-

† Excessive porosity at fracture

B. Test at 871C (1600F), 310 MN/m² (45,000 psi)(2)

Std Size	SM-U	None	-	150.9	-	-	7.1	12.7
			-	219.8	-	-	6.5	9.5
	SM-C	"	-	212.0	200	248	5.8	8.7
0.075 (0.030)	AC-C	"	7620B1A	24.6	18	50	6.3	-
			?7622A4A	32.6	26	63	5.7	-
			?7401A3A	36.5	27	77	3.8	-
			7616C3B	38.0	28	77	5.6	-
	"	997 §	7621A1B	25.9	20	52	4.8	-
			7617D3A	26.2	19	52	5.4	-
	"	1013§§	?7617B3B	7.4	6	16	1.6	-
			7619C2B	10.8	8	25	2.0	-
			7616D1A	12.7	8	24	2.4	-
			7621A4A	26.8	22	48	3.0	-
0.15 (0.060)	AC-U	None	7535C1A	133.0	-	-	8.8	-
			?7534A1A	137.4	-	-	7.9	-
			7534B3B	167.4	-	-	6.5	-
			7539D1A	242.6	-	-	8.0	-
	AC-C	"	7535B3A	46.8	37	68	6.3*	-
			7537A1B	63.0	51	92	4.1	-
			7539A4A	72.2	58	115	5.9	-
			?7538C2A	81.6	70	122	4.7*	-
	"	1021§§	7539A2A	72.4	59	105	7.7	-
			7538C3B	79.1	68	119	7.0*	-
			?7537D2A	79.4	66	117	11.2	-
			?7534B1B	83.3	72	122	9.3	-

C. Test at 871C (1600F), 262 MN/m² (38,000 psi)[2]

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	742.0	-	-	9.8*	9.2
			-	780.0	-	-	6.7	7.1
0.075 (0.030)	AC-U	"	7621A3A	231.4	-	-	4.7	-
			?7621D4A	256.7	-	-	7.0	-
			?7620D3A	280.7	-	-	3.7	-
			7401C1A	296.4	-	-	5.6	-
	AC-U CG	"	8467A3	147.7	-	-	7.0	-
			8467B4B	169.6	-	-	5.5	-
	AC-C	None	?7621B4B	84.9	65	168	5.6	-
			7617A3B	116.4	90	212	4.1	-
			?7619D2B	122.6	97	247	4.3*	-
			?7620C2A	144.6	114	292	5.7	-
	AC-C CG	"	8467B3B	65.4	44	96	5.3	-
			8467A2B	74.7	50	116	4.0*	-
	AC-C	997 §	7620A2A	47.4	35	88	3.8	-
			?7617C2B	51.3	39	103	3.3	-
	"	1013§§	7401D1A	27.8	20	48	1.6	-
			?7622A1A	34.1	25	58	2.4	-
			?7617C2A	50.6	39	102	3.8	-
			7616A4B	94.0	72	165	3.9	-
	SM-U	None	29B	34.2	-	-	3.0	-
			4336C3A	74.4	-	-	5.4*	-
			47B	107.2	-	-	7.7	-
			83A	200.7	-	-	5.8	-
	SM-C	"	67	22.2	16	43	3.5*	-
			? 106A	23.7	17	48	3.2*	-
			? 24B	46.6	34	101	4.4	-
			? 92B	50.9	37	114	5.5*	-
	"	1019§§	39	5.4	4	10	0.7*	-
			108	21.1	15	43	2.5	-
			? 72A	26.8	18	46	2.2	-
			? 92A	35.9	25	68	2.9	-
	SM-C-E-SM	"	14	0.2	-	-	0.7*	-
			42A	3.0	-	-	0.6	-
			4336C1B	11.5	-	-	2.2*	-
	SM-C-E-SM-C	"	45A	2.3	2	6	1.3	-
			33A	3.9	2	8	1.5*	-
			117B	7.3	5	14	0.9*	-
			93A	0.3 †	0.2†	0.8†	0.4 †	
	SM-C-E-SM-C-E	1019/1001§§	? 21A	0†	-	-	-	-
			? 109	3.9	3	9	1.4	-
			83B	4.1	3	10	1.6*	-
			? 65A	5.4	4	13	1.1	-

C. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.15 (0.060)	AC-U	None	7538D4A	299.4	-	-	4.5*	-
			7535C3B	380.3	-	-	6.4	-
			?7539C3B	426.8	-	-	5.6*	-
			7537A4A	596.7	-	-	6.4	-
	AC-C	"	?7534B3A	261.0	222	347	3.7*	-
			7538C3A	266.5	221	370	5.1	-
			?7535D2A	301.9	268	438	5.6	-
			7539A3A	389.7	323	518	4.7	-
	"	1021§§	7539C1B	213.6	188	293	7.4	-
			?7537D1A	230.0	191	315	-	-
			7534A2B	240.7	204	329	8.8	-
			7538B1B	298.6	257	416	12.1	-

D. Test at 982C (1800F), 144 MN/m² (21,000 psi)(2)

Std Size	SM-U	None	-	125 †	-	-	7.0	11.1
			-	147	-	-	6.7	15.9
			-	190 †	-	-	9.2	8.6
			-	129.8	-	-	3.4*	10.0
0.075 (0.030)	AC-U	"	7617D2A	27.2	-	-	5.2	-
			7616A4A	36.2	-	-	5.0	-
			?7619C1A	44.6	-	-	5.6*	-
			?7621C4A	52.5	-	-	9.8	-
	AC-C	"	?7617C1B	29.1	24	59	4.8	-
			?7619B4A	34.7	25	59	6.8	-
			?7620A4A	41.9	33	77	8.5	-
			?7621D1A	42.4	33	88	6.3	-
	"	1013§§	?7620C1B	9.5	7	17	3.9	-
			7616A1A	12.7	11	22	3.5	-
			7619B2A	14.8	12	28	5.3	-
			?7622D3A	15.0	12	28	6.4	-
0.15 (0.060)	AC-U	None	7538D1A	76.0	-	-	7.6	-
			?7535A1A	130.5	-	-	8.5	-
			7537A1A	136.1	-	-	7.6	-
			?7534D1A	136.2	-	-	8.4	-

D. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.15 (0.060)	AC-C	None	?7538B2B	37.7	33	57	3.9*	-
			7534A1B	50.9	45	74	11.5	-
			?7535C2B	54.7	48	78	4.2	-
			?7539D1B	63.5	58	90	7.8	-
	"	1021§§	7538C2B	44.4	37	61	7.6	-
			7539A2B	45.1	38	92	11.1	-
			7534D3A	62.2	55	91	14.9	-
			?7535A4A	83.9	71	116	10.0	-

† Extrapolated from tests run at 190 MN/m² (27,500 psi)

E. Test at 982C (1800F), 117 MN/m (17,000 psi)(2)

Std Size	SM-U	None	-	341.0	-	-	6.5	14.1
	SM-C	"	-	424.2	411	469	8.5	12.2
	AC-C	"	-	440.1	425	488	9.4	26.9
0.075 (0.030)	AC-U	"	?7622A2A	61.7	-	-	3.0	-
			7617A2A	82.1	-	-	3.5	-
			7616D4A	93.0	-	-	5.4	-
			?7620A2B	123.9	-	-	8.0	-
	AC-C	"	?7619C2A	55.8	48	87	10.9	-
			7617A3A	66.0 †	60	110	6.8*	-
			?7616D2A	70.0	60	117	10.0	-
			?7621C4B	104.7	86	171	8.5	-
	"	997§	?7619D2A	70.0	58	104	6.6	-
			7616B1B	87.3	70	129	7.7	-
	"	1013§§	?7617D1A	31.8	27	51	4.3	-
			7619A4B	49.7	42	85	8.8	-
			7622B4B	54.4	45	81	10.4	-
			?7616C3A	90.0	76	143	5.8	-
	SM-U	None	50	65.9	-	-	4.8*	-
			34	75.4	-	-	10.8	-
			96A	78.6	-	-	9.9*	-
			4336A3	87.2	-	-	12.4	-
	SM-C	"	88B	46.1	37	80	8.0	-
			115	50.5	39	86	11.2*	-
			29A	88.1	65	137	7.1	-
			? 51B	113.6	84	178	7.3	-

E. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C	1019§§	4336A2	13.8	11	24	4.5	-
			100A	19.5	16	36	4.2*	-
			7	22.3	18	37	5.1	-
			? 52	39.4	29	63	6.2	-
	SM-C-E-SM	"	33B	8.1	-	-	1.2*	-
			76	11.8	-	-	1.7*	-
			90B	21.1	-	-	3.0*	-
			13A	28.9	-	-	2.3	-
	SM-C-E-SM-C	"	24A	2.5	2	6	1.8	-
			43A	4.2	3	8	1.7*	-
			112	5.7	4	10	1.5	-
			73	8.7	7	13	1.4	-
	SM-C-E-SM-C-E	1019/1001§§	17A	1.9	1	3	1.9*	-
			99	2.2	2	4	2.0	-
			4336C2	3.2	2	5	1.8*	-
			48	3.5	2	6	3.1*	-
0.15 (0.060)	AC-U	None	7534B4A	142.9	-	-	8.6	-
			7538B2A	229.7	-	-	5.0	-
			?7537C4A	237.8	-	-	5.6	-
			?7535B2A	256.7	-	-	13.0	-
	AC-C	"	?7538C1B	154.2	131	196	6.4	-
			?7537A2B	167.9	149	213	6.3	-
			?7535D2B	201.0	171	249	10.6	-
			?7534B1A	210.5	189	267	7.5	-
	"	1021§§	?7538D4B	118.5	108	155	5.6	-
			?7535B2B	161.4	144	216	6.1	-
			?7534C1B	253.3	231	336	10.1	-
			7535A3A	269.2	237	336	8.3	-

† Extrapolated from test run at 138 MN/m² (20,100 psi)

F. Test at 1093C (2000F), 34.5 MN/m² (5,000 psi)(2)

Std Size	SM-U	None	-	42.2	-	-	2.9	3.5
	SM-C	"	-	235.1	230	247	4.7*	6.5
0.075 (0.030)	AC-U	"	?7617D1B	13.2 †	-	-	3.6*	-
			7620D2A	34.4	-	-	4.4*	-
			7616A2A	68.6	-	-	22.4	-
			7617C1A	70.7	-	-	16.0	-
	AC-U CG	"	8467D3A	46.0	-	-	6.7	-
			8467C4A	81.1	-	-	7.3	-

F. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.075 (0.030)	AC-C	None	?7622B4A	44.3	40	53	10.4	-
			?7621B4A	46.1	43	60	9.8	-
			?7620C4A	63.2	59	82	12.0	-
			?7622C1A	67.0	62	82	14.2	-
	AC-C CG	"	8467D3B	28.8	25	34	7.2	-
			8467B2B	151.3	132	171	4.9	-
	AC-C	1013§§	?7622D2	33.7	31	42	3.8	-
			?7401A2A	47.1	44	60	6.2	-
			7616D1B	59.1	55	76	6.9	-
			7622C3A	90.2	83	115	5.4	-
	SM-U	None	51A	Overtemperature in Test				-
			37	43.2	-	-	10.8*	-
			122B	71.0	-	-	13.9	-
			? 103	82.4	-	-	9.5	-
	SM-C	"	? 46B	25.1	23	32	8.0*	-
			35	34.0	29	41	8.7	-
			80	47.5	43	67	6.5	-
			4336A4	67.4	60	87	6.1	-
	"	1019§§	4336C1A	24.3	22	31	6.9	-
			30	26.2	23	33	4.2*	-
			74	30.8	28	41	6.4	-
			93B	36.1	33	49	10.1	-
	SM-C-E-SM	"	100B	11.7 †	-	-	1.8*	-
			43B	12.2 †	-	-	1.1*	-
			117B	18.4	-	-	5.0*	-
	SM-C-E-SM-C	"	10	1.7 †	1	3	2.0*	-
			54B	4.9	4	6	1.9	-
			79	7.9	7	10	2.5	-
			4336B4	9.1	8	14	2.3*	-
	SM-C-E-SM-C-E	1019/1001§§	13B	5.2	5	7	3.1*	-
			? 42B	8.9	8	12	4.1*	-
			? 95	10.2	9	14	3.0	-
			71	13.5	12	18	2.7*	-
0.15 (0.060)	AC-U	None	7534C3A	35.9	-	-	4.3*	-
			7538A4A	94.9	-	-	2.2	-
			?7539B2B	101.0	-	-	5.8	-
			7537B1B	121.2	-	-	3.4*	-

F. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.15 (0.060)	AC-C	None	?7535D4A	96.7	91	109	9.2	-
			?7539B1B	107.5	101	120	14.1	-
			?7538A2A	110.4	103	121	5.1	-
			?7534C2A	145.3	138	164	4.0	-
	"	1021§§	?7538B4B	104.1	100	117	4.3	-
			7535C4A	105.5	100	118	3.9*	-
			7531A3A	158.7	150	179	5.4	-
			?7538A3B	166.1	156	182	5.1	-

†† Specimen Condition: AC = As cast, SM = Surface machined: removed 0.05 to 0.07 mm (0.0025 inch) for initial SM on 0.075 cm specimens (each side); 0.12 to 0.13 mm (0.005 inch) for SM after exposure on 0.075 cm specimens (each side) and on radius of standard size bars, U = Uncoated, C = Coated, E = Exposed, CG = Coarse grained

§ Exposure temperature = 899C (1650F)
§§ " " = 982C (1800F)

* Specimens failed at or near end of gage length.
† " " in grip section. True life should be higher.

(2) Life based on stress calculated using original metal thickness before coating (test load for this stress).

(1) Life based on stress calculated using overall thickness, including coating, extrapolated from (2).

(3) Life based on stress calculated using unaffected remaining metal thickness, extrapolated from (2).

Table IX Stress Rupture Test Results: Rene 80 Heat B353

A. Test at 760C (1400F), 565 MN/m² (82,000 psi)(2)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs. (2)	Life, hrs. (1)	Life, hrs. (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	>71.7<136.7 -		-	9.9	15.8
	SM-C	"	-	69.8	65	87	5.0	6.9
			-	87 †	82	105	2.3	4.5
			-	104 †	98	125	3.8	7.0
			-	110	104	133	4.4	9.6
			-	111	105	134	1.9	7.2
			-	154	144	184	3.0	8.2
			-	158 †	148	190	3.0	9.3
			-	208	195	250	4.4	8.2
0.038 (0.015)	AC-U	"	75	14.2	-	-	1.1	-
			92	17.3†	-	-	-	-
			7181AA	23.1	-	-	-	-
			7194BB	69.5	-	-	4.4	-
	AC-C	"	7185B	0.05	0.02	0.3	0.7	-
			87	0.4	0.2	2	0.0*	-
			74	0.8†	0.3†	3 †	1.3†	-
			7071AA	19.2†	9 †	125 †	- †	-
	"	1001	7**	Failed on Loading †			-	-
			7181AB	" " " †			-	-
			7186BB	" " "			0.1	-
			7194BA	1.1	0.6	8	0.1	-
0.075 (0.030)	AC-U	None	-	26 †	-	-	7.9	-
			-	75 †	-	-	8.6	-
			-	85 †	-	-	10.3	-
			-	98 †	-	-	9.0	-
	AC-C	"	-	6 †	4	11	1.5	-
			-	7 †	5	12	3.9	-
			-	17 †	12	32	3.7	-
			-	23 †	16	42	4.5	-
			-	35 †	24	64	4.8	-

B. Test at 871C (1600F), 310 MN/m² (45,000 psi)[2]

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs. (2)	Life, hrs. (1)	Life, hrs. (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	199.6	-	-	8.4	14.3
	SM-C	"	-	115 †	107	128	-	-
			-	120 †	112	133	3.9	13.0
			-	126 †	118	140	4.9	8.7
			-	148 †	139	165	6.8	11.1
0.038 (0.015)	AC-U	"	91	4.7†	-	-	-	-
			104	22.9	-	-	5.5	-
			7197AA	55.7	-	-	6.8	-
			7070AB	65.3	-	-	7.7	-
	AC-C	"	68	Failed on Loading			-	-
			7194AB	3.8	2	11	-*	-
			112	4.4	2	10	3.0*	-
			7190BB	6.5 †	4	19	3.9	-
	"	1001	7196AB	0.1 †	0.1 †	0.3 †	-	-
			7187AA	0.2	0.1	0.4	0.0	-
			7072B	0.5	0.3	1	0.0	-
			7071BA	6.8	4	15	1.5	-
0.075 (0.030)	AC-U	None	4543A3A	53.6	-	-	10.5	-
	AC-C	"	-	?0.1	0.1	0.2	-	-
			-	31	20	49.2	6.7	-

C. Test at 871C (1600F), 262 MN/m² (38,000 psi)[2]

Std Size	SM-U	None	-	511.1	-	-	12.4	17.0
	SM-C	"	-	419 †	398	460	4.7	-
			-	519 †	493	570	6.3	-
			-	698.7	664	768	11.3	18.7
0.038 (0.015)	AC-U	"	7190BA	12.2†	-	-	-	-
			97	24.1†	-	-	-	-
			7071GC	50.3†	-	-	-	-
			84	53.4	-	-	1.9	-
	AC-C	"	78	Overtemperature in Test			-	-
			8**	2.0	1	4	1.2*	-
			7186BA	8.0	5	24	1.4	-
			110	49.0	29	95	3.0	-
	"	1001	2**	2.0†	1 †	6 †	-	-
			7184AA	2.8	2	8	0.0*	-
			7197B	15.9	11	45	7.6	-
			7192AA	117.1	83	313	-	-

C. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.075 (0.030)	AC-U	None	-	200 †	-	-	9.3	-
			-	225 †	-	-	6.7	-
			-	240 †	-	-	6.6	-
	AC-C	"	-	80 †	67	115	5.5*	-
			-	161 †	133	230	6.3	-

D. Test at 982C (1800F), 189 MN/m² (27,500 psi)(2)

Std Size	SM-U	None	-	6.5	-	-	3.7	9.5
			-	27.3	-	-	8.8	12.7
			-	34.8	-	-	10.7	16.5
			-	35.8	-	-	11.3	16.1

E. Test at 982C (1800F), 145 MN/m² (21,000 psi)(2)

Std Size	SM-C	None	-	127	119	135.0	-	-
			-	140	132	149.5	10.6	11.1
			-	149	139	158.3	5.8	16.6
			-	366 †	343	390	5.2	14.2
0.038 (0.015)	AC-U	"	65	1.4	-	-	2.2*	-
			7187AB	3.2†	-	-	-	-
			99	6.1	-	-	2.5	-
			7186AB	10.3	-	-	3.7	-
	AC-C	"	90	1.6	1	4	1.7	-
			113	1.6	1	3	1.9	-
			7184AB	2.6	2	8	2.3	-
			7192BB	<16.2	<11	<35	1.7	-
	"	1001	7192CB	1.5	1	4	3.2	-
			7188AB	1.6	1	4	3.0	-
			7071DB	1.7	1	4	1.4	-
			7191AA	20.0	15	47	2.0	-
0.075 (0.030)	AC-U	None	4541C3B	19.3	-	-	11.9	-
			4544D2A	30.4	-	-	9.3	-
	AC-C	"	-	17	14	22.8	8.0	-

F. Test at 932C (1800F), 117 MN/m² (17,000 psi)[2]

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	197.2	-	-	5.3	11.4
	SM-C	"	-	267.8	254	295	10.8	26.2
			-	435	423	470	9.4	-
0.038 (0.015)	AC-U	"	7192CA	Failed on Loading			5.8	-
			94	9.0	-	-	2.1*	-
			80	10.0	-	-	2.0*	-
			7185AA	24.2	-	-	1.5	-
	AC-C	"	7071BB	1.2§	1	2	1.1	-
			70	3.6	3	9	1.9	-
			7189A	19.7	14	47	2.0	-
			106	20.2	15	41	2.5	-
	"	1001	6**	1.8	1	5	4.0*	-
			7190A	3.8	3	8	3.5	-
			7193AA	5.0	4	9	2.8*	-
			7186AA	6.3	5	14	3.0	-
0.075 (0.030)	AC-U	None	-	81	-	-	4.9	-
			-	87	-	-	5.0	-
			-	148	-	-	8.0	-
	AC-C	"	-	39 †	33	60	2.0	-
			-	73 †	62	112	6.2	-
			-	84 †	71	129	10.5	-
			-	120 †	102	184	6.2	-

§ Abnormal damage to specimen prior to test

G. Test at 1083C (2000F), 34.5 MN/m² (5,000 psi)

Std Size	SM-C	None	-	41.5	40	44	-	11.6
			-	59.2	58	62	1.1	3.4
			-	146.5	144	152	4.0	4.0
0.038 (0.015)	AC-U	"	7189BA	10.1	-	-	3.7*	-
			88	25.0	-	-	5.6	-
			79	29.7	-	-	8.9	-
			7193AB	43.7	-	-	8.9	-
	AC-C	"	69	4.9	4	7	3.2*	-
			7071GB	9.4	8	15	4.7	-
			109	17.1	14	23	3.6	-
			7183AA	32.5	29	49	2.6	-

G. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.038 (0.015)	AC-C	1001	7071DA	5.0	4	8	3.6	-
			7070AA	10.3	9	16	2.9	-
			7192AB	13.5	10	20	2.9*	-
			7188BB	19.0	17	29	3.8	-
0.075 (0.030)	AC-U	None	4543A4	35.0	-	-	20.2	-
			4540D4A	47.9	-	-	19.2	-
	AC-C	"	4541D4	62.0	56	74	14.6	-

† Tested at slightly different stress. Life extrapolated to indicated stress.

†† Specimen Condition: AC = As cast, SM = Surface machined: U = Uncoated, C = Coated

Exposure temperature = 982C (1800F)

* Specimens failed at or near end of gage length.
† " " in grip section. True life should be higher.

(2) Life based on stress calculated using original metal thickness before coating (test load for this stress).

(1) Life based on stress calculated using overall thickness, including coating, extrapolated from (2).

(3) Life based on stress calculated using unaffected remaining metal thickness, extrapolated from (2).

Table X Average Stress Rupture Properties: Rene 80

A. Test at 760C (1400F), 565 MN/m² (82,000 psi)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B322				Heat B353			
		Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.
Std Size	SM-U/C	178.6	7.4	-	3	105.6	4.2	-	9
0.038 (0.015)	AC-U	-	-	-	-	28.4	2.8	0.0478 (0.0188)	3
	AC-C	-	-	-	-	~ 5↑	0.6↑	0.0439 (0.0173)	4
	AC-C-E	-	-	-	-	<1.1	0.1	0.0414 (0.0163)	4
0.075 (0.030)	AC-U	71.0	9.4	0.0724 (0.0285)	4	63.5	9.0	?	4
	AC-C	† 15.6	4.0	0.0780 (0.0307)	4	14.2	3.7	?	5
	AC-C-E	<2	0.4	0.0734 (0.0289)	4	-	-	-	-
	SM-U	5.0	6.6*	0.0620 (0.0244)	4	-	-	-	-
	SM-C	5.6	4.2*	0.0605 (0.0238)	3	-	-	-	-
	SM-C-E	† 17.5	2.1	0.0620 (0.0244)	4	-	-	-	-
	SM-C-E-SM	† 8.8↑	1.0*	0.0511 (0.0201)	4	-	-	-	-
	SM-C-E-SM-C	0.1↑	0.7*	0.0493 (0.0194)	4	-	-	-	-
	SM-C-E-SM-C-E	F.O.L	-	0.0566 (0.0223)	4	-	-	-	-
0.15 (0.060)	AC-U	157.8	8.5*	0.1549 (0.0610)	4	-	-	-	-
	AC-C	72.4	6.8	0.1463 (0.0576)	4	-	-	-	-
	AC-C-E	65.2	4.0	0.1544 (0.0608)	3	-	-	-	-

B. Test at 871C (1600F), 310 MN/m² (45,000 psi)

Std Size	SM-U/C	191.6	6.5	-	3	126.7	5.2	-	4
0.038 (0.015)	AC-U	-	-	-	-	† 33.9↑	6.7	0.0448 (0.0176)	4
	AC-C	-	-	-	-	3.6	~3	0.0438 (0.0173)	4
	AC-C-E	-	-	-	-	† 1.9↑	0.5	0.0470 (0.0185)	4

B. (Cont.)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B322				Heat B353			
		Average Life hrs	Av'g. Elong, %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong %	Average Thickness cm (inch)	No. of Spec.
0.075 (0.030)	AC-U	-	-	-	-	53.6	10.5	0.0737 (0.0290)	1
	AC-C	32.5	5.4	0.0747 (0.0294)	4	31.0	6.7	?	1
	AC-C-E	12.8	2.3	0.0790 (0.0311)	4	-	-	-	-
0.15 (0.060)	AC-U	165.1	7.8	0.1575 (0.0620)	4	-	-	-	-
	AC-C	64.6	5.3*	0.1527 (0.0601)	4	-	-	-	-
	AC-C-E	78.5	8.8*	0.1562 (0.0615)	4	-	-	-	-

C. Test at 871C (1600F), 262 MN/m^2 (38,000 psi)

Std Size	SM-U/C	760.8	8.3*	-	2	527.9	8.7	-	4
0.038 (0.015)	AC-U	-	-	-	-	29.8↑	1.9	0.0476 (0.0188)	4
	AC-C	-	-	-	-	† 13.9	1.9*	0.0457 (0.0180)	3
	AC-C-E	-	-	-	-	† 22.8↑	3.8*	0.0435 (0.0170)	4
0.075 (0.030)	AC-U	265.1	5.3	0.0747 (0.0294)	4	221.0	7.5	?	3
	AC-C	115.1	4.9*	0.0739 (0.0291)	4	113.5	5.9*	?	2
	AC-C-E	46.1	2.9	0.0742 (0.0292)	4	-	-	-	-
	SM-U	85.7	5.5*	0.0617 (0.0243)	4	-	-	-	-
	SM-C	33.4	4.2*	0.0632 (0.0249)	4	-	-	-	-
	SM-C-E	18.2	2.1*	0.0617 (0.0243)	4	-	-	-	-
	SM-C-E-SM	† 4.9	1.2*	0.0564 (0.0222)	3	-	-	-	-
	SM-C-E-SM-C	4.0	1.2*	0.0516 (0.0203)	3	-	-	-	-
	SM-C-E-SM-C-E	4.4	1.4*	0.0513 (0.0202)	3	-	-		
0.15 (0.060)	AC-C	412.7	5.7*	0.1547 (0.0609)	4	-	-	-	-
	AC-C	300.8	4.8*	0.1488 (0.0586)	4	-	-	-	-
	AC-C-E	243.8	9.4	0.1499 (0.0590)	4	-	-	-	-

D. Test at 982C (1800F), 145 MN/m^2 (21,000 psi)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B322 Average Life hrs	Heat B322 Av'g. Elong. %	Heat B322 Average Thickness cm (inch)	Heat B322 No. of Spec.	Heat B353 Average Life hrs	Heat B353 Av'g. Elong. %	Heat B353 Average Thickness cm (inch)	Heat B353 No. of Spec.
Std Size	SM-U/C	145.9	6.6*	-	4	176.5	7.2	-	4
0.038 (0.015)	AC-U	-	-	-	-	4.1↑	2.8*	0.0470 (0.0185)	4
	AC-C	-	-	-	-	1.9↑	1.8	0.0445 (0.0175)	4
	AC-C-E	-	-	-	-	3.0	2.4	0.0480 (0.0189)	4
0.075 (0.030)	AC-U	39.0	6.4*	0.0759 (0.0298)	4	24.2	10.6	0.0762 (0.0300)	2
	AC-C	36.6	6.6	0.0775 (0.0305)	4	17.0	8.0	?	1
	AC-C-E	12.8	4.8	0.0762 (0.0300)	4	-	-	-	-
0.15 (0.060)	AC-U	116.4	8.0	0.1544 (0.0608)	4	-	-	-	-
	AC-C	50.8	6.9	0.1468 (0.0578)	4	-	-	-	-
	AC-C-E	56.9	10.9	0.1476 (0.0581)	4	-	-	-	-

E. Test at 982C(1800F), 117 MN/m^2 (17,000 psi)

Std Size	SM-U/C	399.3	8.1	-	3	284.3	8.5	-	3
0.038 (0.015)	AC-U	-	-	-	-	9.8	2.9*	0.0434 (0.0171)	4
	AC-C	-	-	-	-	11.3	2.1	0.0429 (0.0169)	3
	AC-C-E	-	-	-	-	3.8	3.3	0.0460 (0.0181)	4
0.075 (0.030)	AC-U	87.4	5.0	0.0752 (0.0296)	4	101.4	6.0	?	3
	AC-C	72.1	9.1*	0.0739 (0.0291)	4	73.2	6.2	?	4
	AC-C-E	52.7	7.3	0.0772 (0.0304)	4	-	-	-	-
	SM-U	76.4	9.5*	0.0617 (0.0243)	4	-	-	-	-
	SM-C	69.5	8.4*	0.0620 (0.0244)	4	-	-	-	-
	SM-C-E	22.1	5.0*	0.0594 (0.0234)	4	-	-	-	-
	SM-C-E-SM	15.5	2.1*	0.0544 (0.0214)	4	-	-	-	-
	SM-C-E-SM-C	4.8	1.6*	0.0533 (0.0210)	4	-	-	-	-
	SM-C-E-SM-C-E	2.6	2.2*	0.0544 (0.0214)	4	-	-	-	-

E. (Cont.)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B322				Heat B353			
		Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.
0.15 (0.060)	AC-U	211.6	8.1	0.1519 (0.0598)	4	-	-	-	-
	AC-C	181.9	7.7	0.1557 (0.0613)	4	-	-	-	-
	AC-C-E	190.0	7.5	0.1499 (0.0590)	4	-	-	-	-

F. Test at 1093C (2000F), 34.5 MN/m^2 (5,000 psi)

Std Size	SM-U/C	† 119.1	3.8*	-	2	71.1	2.6*	-	3
0.038 (0.015)	AC-U	-	-	-	-	23.9	6.8*	0.0470 (0.0185)	4
	AC-C	-	-	-	-	12.6	3.5*	0.0445 (0.0175)	4
	AC-C-E	-	-	-	-	10.7	3.3	0.0434 (0.0171)	4
0.075 (0.030)	AC-U	55.1	14.3*	0.0747 (0.0294)	3	40.9	19.7	0.0729 (0.0287)	2
	AC-C	54.2	11.6	0.0790 (0.0311)	4	62.0	14.6	0.0787 (0.0310)	1
	AC-C-E	53.9	5.6	0.0724 (0.0285)	4	-	-	-	-
	SM-U	63.2	11.4*	0.0620 (0.0244)	3	-	-	-	-
	SM-C	40.7	7.3*	0.0605 (0.0238)	4	-	-	-	-
	SM-C-E	29.0	6.9*	0.0607 (0.0239)	4	-	-	-	-
	SM-C-E-SM	13.8†	3.2*	0.0488 (0.0192)	3	-	-	-	-
	SM-C-E-SM-C	7.1	2.2*	0.0521 (0.0205)	3	-	-	-	-
	SM-C-E-SM-C-E	8.9	3.2*	0.0539 (0.0209)	4	-	-	-	-
0.15 (0.060)	AC-U	80.4	4.3*	0.1532 (0.0603)	4	-	-	-	-
	AC-C	113.6	8.1	0.1501 (0.059[illegible])	4	-	-	-	-
	AC-C-E	130.4	4.7*	0.1527 (0.060[illegible])	4	-	-	-	-

†† Specimen Condition: AC= As cast, SM = Surface machined (see footnote of Table VIII),U= Uncoated, C= Codep B-1 coated, E = Exposed ∿ 1000 hrs at 982C.

* Specimens failed at or near end of gage length.

† " " in grip section. True life should be higher.

Stress rupture lives are logarithmic or log/linear averages (see text), and are based on method 2 for stress calculation. † indicates log/linear average.

Table XI Tensile Properties: Rene 120 Heat B325

A. Test at Room Temperature

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	-	859 (124.6)	-	-	1017 (147.4)	-	6.0*	10.4
			-	-	905 (131.1)	-	-	997 (144.6)	-	5.5*	11.7
	SM-C	"	-	794 (115.2)	812 (117.9)	828 (120.0)	1010 (146.5)	1023 (148.5)	1051 (152.4)	7.0	11.0
0.075 (0.030)	AC-U	"	A24337	-	814 (118.0)	-	-	921 (133.5)	-	3.9	-
			D14337B	-	850 (123.2)	-	-	921 (133.5)	-	2.8	-
			C14337	-	857 (124.2)	-	-	1011 (146.7)	-	6.0	-
			A48581A	-	879 (127.5)	-	-	962 (139.5)	-	4.0	-
	AC-C	"	?A48577	751 (108.9)	794 (115.1)	892 (130.9)	888 (128.8)	940 (136.2)	1068 (154.8)	5.5*	-
			D28581B	753 (109.2)	798 (115.7)	914 (132.7)	907 (131.6)	960 (139.1)	1100 (159.6)	7.5	-
			?B28578B	754 (109.4)	788 (114.3)	892 (130.9)	862 (125.0)	901 (130.7)	1030 (149.3)	4.0*	-
			C28577B	784 (113.8)	834 (121.0)	939 (136.2)	824 (119.4)	876 (127.0)	989 (143.3)	2.0*	-
	"	997	?A18578B †	-	-	-	560 (81.2)	591 (85.6)	667 (96.6)	0.8*	-
			?B28578A	605 (87.7)	636 (92.2)	707 (102.7)	634 (92.0)	666 (96.6)	741 (107.6)	2.6	-
			?C18581A	644 (93.3)	681 (98.7)	771 (111.8)	666 (96.5)	705 (102.2)	797 (115.7)	0.9	-
			?B18579A	648 (94.0)	684 (99.3)	761 (110.5)	654 (94.7)	690 (100.0)	768 (111.4)	1.8	-
0.15 (0.060)	AC-U	None	B28237A	-	879 (127.6)	-	-	1017 (147.5)	-	7.1	-
	AC-C	"	A18241A	774 (112.2)	789 (114.5)	851 (123.5)	955 (138.5)	975 (141.3)	1049 (152.2)	8.0	-
			D18240A	776 (112.5)	801 (116.1)	849 (123.1)	969 (140.6)	1001 (145.1)	1060 (153.9)	8.5	-
			B38237A	790 (114.7)	814 (118.0)	861 (124.9)	960 (139.1)	987 (143.2)	1043 (151.5)	6.0*	-
			C48241A	797 (115.6)	816 (118.3)	872 (126.4)	1011 (146.8)	1036 (150.2)	1106 (160.5)	9.0	-
	"	993	C18241A	643 (93.2)	662 (96.0)	708 (102.8)	779 (113.0)	803 (116.5)	858 (124.6)	5.8	-
			?A48237A	652 (94.6)	674 (97.7)	727 (105.6)	714 (103.3)	736 (106.8)	795 (115.3)	2.6	-
			?B48237B	664 (96.3)	677 (98.2)	730 (105.9)	774 (112.3)	790 (114.6)	853 (123.8)	4.1	-
			?D28240B	752 (109.0)	766 (111.1)	836 (121.1)	781 (113.3)	797 (115.7)	869 (126.0)	5.4	-

B. Test at 871C (1600F)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	-	619 (89.9)	-	-	791 (114.7)	-	3.0*	5.7
			-	-	639 (92.6)	-	-	745 (108.0)	-	3.0	6.4
0.075 (0.030)	AC-U	"	A44337	-	607 (88.0)	-	-	680 (98.6)	-	2.3*	-
			D48578A	-	615 (89.2)	-	-	681 (98.7)	-	4.1*	-
			A34337	-	623 (90.4)	-	-	670 (97.2)	-	1.1	-
			C3858'B	-	626 (90.7)	-	-	726 (105.2)	-	3.5	-
			B14337	-	646 (93.7)	-	-	679 (98.5	-	2.3*	-
			D24337	-	651 (94.4)	-	-	745 (108.0)	-	3.3*	-
			B48578A	-	656 (95.2)	-	-	766 (111.0)	-	4.6	-
			?C28581A	-	677 (98.2)	-	-	731 (106.0)	-	3.3*	
	AC-C	"	B18579B	491 (71.4)	515 (74.8)	579 (83.9)	646 (93.8)	676 (98.2)	761 (110.3)	2.9	-
			?D18581B	526 (76.4)	559 (81.1)	631 (91.6)	632 (91.7)	671 (97.4)	759 (110.1)	2.8	-
			C18577A	532 (77.2)	551 (80.0)	628 (91.1)	652 (94.6)	675 (98.0)	769 (111.6)	2.7	-
			?A38578A	545 (79.1)	566 (82.1)	665 (96.5)	614 (89.0)	636 (92.4)	749 (108.6)	2.0	-
	"	997	?C28578A	-	-	-	340 (49.4)	361 (52.4)	408 (59.1)	0.2*	-
			A48579A	545 (79.1)	567 (82.3)	642 (93.2)	631 (91.6)	657 (95.4)	746 (108.1)	1.6	-
			B48578B	570 (82.6)	592 (85.9)	679 (98.5)	582 (84.5)	605 (87.8)	694 (100.7)	1.7*	-
			B48581B	-	-	-	695 (100.8)	723 (104.8)	836 (121.2)	0.9*	-
0.15 (0.060)	AC-U	None	B38240A	-	605 (87.7)	-	-	726 (105.2)	-	4.2	-
	AC-C	"	?D28237A	561 (81.4)	577 (83.7)	609 (88.4)	722 (104.8)	744 (107.9)	785 (113.9)	6.3	-
			C48241B	615 (89.2)	635 (92.1)	676 (98.1)	709 (102.8)	732 (106.1)	779 (113.0)	2.4	-
			?B48240B	622 (90.3)	642 (93.1)	677 (98.3)	689 (100.0)	712 (103.2)	751 (109.0)	1.4*	-
			?A38241B	627 (91.0)	645 (93.6)	677 (98.2)	764 (110.9)	786 (114.0)	823 (119.5)	3.2*	-
	"	993	?D28241A	-	-	-	574 (83.3)	593 (86.1)	636 (92.3)	1.2	-
			?B18237B	-	-	-	590 (85.6)	609 (88.4)	661 (96.0)	1.0	-
			C48240B	575 (83.4)	594 (86.1)	641 (93.0)	591 (85.7)	610 (88.5)	659 (95.6)	0.5	-
			?A48240B	587 (85.2)	605 (87.7)	644 (93.4)	621 (90.2)	641 (92.9)	682 (98.9)	2.1*	-

C. Test at 982C (1800F)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	-	348 (50.5)	-	-	495 (71.8)	-	2.0*	3.5
	SM-C	"	-	366 (53.1)	372 (53.9)	381 (55.2)	483 (70.1)	489 (71.0)	503 (72.9)	2.0*	1.9
0.075 (0.030)	AC-U	"	D14337A	-	353 (51.2)	-	-	414 (60.0)	-	1.2*	-
	AC-C	"	?C18577B	-	-	-	425 (61.7)	449 (65.1)	508 (73.8)	1.0	-
			?A48578B	367 (53.3)	382 (55.4)	453 (65.7)	426 (61.8)	443 (64.2)	525 (76.1)	1.0	-
			?B28581A	393 (57.0)	414 (60.1)	485 (70.3)	429 (62.3)	453 (65.7)	530 (76.9)	1.9	-
	"	997	?B48581A	-	-	-	338 (49.0)	358 (51.9)	400 (58.0)	0.2*	-
			?C48577B	280 (40.6)	291 (42.2)	329 (47.7)	393 (57.0)	409 (59.3)	461 (66.9)	3.3	-
			A28576	332 ((48.2)	348 (50.5)	399 (57.9)	351 (51.0)	368 (53.4)	421 (61.1)	0.8*	-
			D38578B	361 (52.4)	382 (55.4)	423 (61.4)	394 (57.1)	416 (60.4)	461 (66.9)	1.5	-
0.15 (0.060)	AC-U	None	B28240A	-	356 (51.6)	-	-	477 (69.2)	-	5.2*	-
	AC-C	"	?A18237A	347 (50.3)	358 (51.9)	383 (55.5)	438 (63.6)	451 (65.5)	484 (70.2)	2.1*	-
			C18241B	370 (53.6)	381 (55.2)	404 (58.6)	478 (69.3)	491 (71.4)	522 (75.8)	2.2	-
			D18241B	374 (54.3)	386 (56.0)	412 (59.9(	449 (65.2)	463 (67.2)	496 (72.0)	3.0	-
			C38241A	383 (55.6	394 (57.2)	417 (60.5)	413 (60.0)	426 (61.8)	449 (65.2)	1.5	-
	"	993	C18240B	324 (47.0)	332 (48.2)	352 (51.1)	390 (56.6)	401 (58.1)	424 (61.5)	0.5	-
			B18237A	331 (48.0)	339 (49.2)	363 (52.7)	350 (50.8)	359 (52.1)	385 (55.8)	0.9*	-
			?D38241A	335 (48.6)	345 (50.1)	373 (54.1)	367 (53.3)	378 (54.9)	409 (59.3)	0.4	-
			?A28240B	347 (50.3)	354 (51.3)	386 (56.0)	369 (53.6)	377 (54.7)	411 (59.7)	0.3*	-

All exposures at 982C (1800F)

* Specimens failed at or near end of gage length.

† Casting defect 0.015 x 0.030 cm (0.006 x 0.012 inch) present near edge of fracture.
†† Specimen condition: AC = As cast, SM = Surface machined, U = Uncoated, C = Coated.

(1) Strength based on external specimen dimensions including coating.
(2) " " " original specimen dimensions before coating.
(3) " " " unaffected remaining metal thickness (below coating additive layer and diffusion zone).

Table XII Tensile Test Results: Rene 120 Heat B415

A. Test at Room Temperature

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	-	896 (130.0)	-	-	969 (140.5)	-	6.0	7.9
			-	-	852 (123.5)	-	-	993 (144.0)	-	11.0	8.4
	SM-C	"	-	839 (121.7)	848 (123.0)	865 (125.4)	994 (144.1)	1004 (145.5)	1023 (148.4)	9.6	10.2
0.038 (0.015)	AC-U	"	4A	-	709 (102.8)	-	-	876 (127.0)	-	9.0	-
	AC-C	"	8	649 (94.2)	707 (102.6)	795 (115.3)	680 (98.6)	741 (107.4)	832 (120.7)	2.4*	-
0.075 (0.030)	AC-U	"	D42774B	-	836 (121.3)	-	-	1057 (153.3)	-	8.6	-
			C11374A	-	852 (123.5)	-	-	1125 (163.2)	-	12.3	-
			A21376A	-	856 (124.2)	-	-	1007 (146.0)	-	5.5	-
			B21375B	-	874 (126.8)	-	-	1112 (161.3)	-	12.4	-
	AC-C	"	A31376	720 (104.	777 (112.7)	892 (129.4)	785 (113.9)	847 (122.9)	974 (141.2)	2.9	-
			D41377	734 (106.5)	782 (113.4)	885 (128.4)	818 (118.6)	871 (126.3)	986 (143.0)	2.4	-
			B22771	775 (112.4)	830 (120.4)	886 (128.5)	857 (124.3)	918 (133.2)	980 (142.1)	3.4	-
			B27658A	816 (118.4)	849 (123.2)	940 (136.3)	888 (128.8)	924 (134.0)	1022 (148.3)	2.7	-
	"	1040	B129354B	517 (75.0)	548 (79.5)	578 (83.8)	518 (75.2)	550 (79.7)	579 (84.0)	1.4	-
		"	B129354A	549 (79.7)	586 (85.0)	622 (90.2)	549 (79.7	586 (85.0)	622 (90.2)	1.2	-
		822	D21376A	563 (81.6)	603 (87.4)	701 (101.6)	563 (81.6)	603 (87.4)	701 (101.6)	1.5	-
		"	B41377	568 (82.4)	603 (87.4)	668 (96.9)	591 (85.7)	634 (92.0)	709 (102.8)	1.6	-
	SM-U	None	B429354B	-	779 (113.0)	-	-	930 (134.9)	-	8.3	-
			B42772A	-	827 (119.9)	-	-	943 (136.8)	-	6.7	-
			B32772	-	850 (123.3)	-	-	1063 (154.2)	-	8.5	-
	SM-C	"	B429354A	708 (102.7)	752 (109.0)	813 (117.9)	784 (113.7)	832 (120.6)	900 (130.6)	3.0	-
			D329354A	722 (104.7)	751 (108.9)	829 (120.2)	759 (110.1)	789 (114.5)	872 (126.4)	1.9	-
			B12771B	789 (114.4)	831 (120.5)	935 (135.6)	869 (126.1)	916 (132.9)	1030 (149.4)	2.9*	-
	"	1014	A36252B	624 (90.5)	656 (95.1)	732 (106.2)	624 (90.5)	656 (95.1)	732 (106.2)	1.3	-
		1040	A47659B	639 (92.7)	671 (97.3)	747 (108.4)	645 (93.5)	676 (98.1)	754 (109.4)	1.2	-
		1000	D46252B	676 (98.1)	712 (103.2)	785 (113.8)	679 (98.5)	714 (103.6)	787 (114.2)	1.9	-
	SM-C-E-SM	906	B32776	-	636 (92.2)	-	-	697 (101.1)	-	1.0	-
			A32773	-	638 (92.6)	-	-	681 (98.8)	-	1.5	-
			D42771B	-	-	-	-	765 (111.0)	-	2.2	-

A. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C-E-SM-C	906	A32774	481 (69.7)	545 (79.0)	601 (87.1)	481 (69.7)	545 (79.0)	601 (87.1)	1.0	-
			B42777A	553 (80.2)	610 (88.5)	672 (97.4)	559 (81.1)	617 (89.5)	679 (98.5)	0.9	-
			C32777A	574 (83.3)	643 (93.3)	701 (101.7)	595 (86.3)	666 (96.6)	727 (105.4)	1.5	-
	SM-C-E-SM-C-E	906/857	B32773	407 (59.0)	465 (67.4)	516 (74.8)	407 (59.0)	465 (67.4)	516 (74.8)	0.6*	-
			B22776	412 (59.7)	459 (66.5)	498 (72.2)	412 (59.7)	459 (66.5)	498 (72.2)	0.4*	-
			A32777A	417 (60.5)	462 (67.0)	510 (73.9)	417 (60.5)	462 (67.0)	510 (73.9)	0.3	-
0.15 (0.060)	AC-U	None	C17660A	-	857 (124.3)	-	-	1006 (145.9)	-	10.6	-
			B16401A	-	883 (128.1)	-	-	923 (133.6)	-	2.9	-
			A32769	-	903 (130.9)	-	-	1060 (153.7)	-	7.0*	-
			D22765	-	905 (131.2)	-	-	1072 (155.5)	-	8.1	-
	AC-U CCG	"	A46401A	-	811 (117.6)	-	-	884 (128.2)	-	3.7	-
			D16159B	-	845 (122.5)	-	-	946 (137.2)	-	6.5	-
	AC-C	"	C46251A	787 (114.1)	815 (118.2)	841 (122.0)	935 (135.6)	969 (140.5)	999 (144.9)	6.9	-
			A36251B	838 (121.6)	856 (124.1)	892 (129.4)	951 (137.9)	971 (140.8)	1012 (146.8)	4.4	-
			C27660A	840 (121.9)	858 (124.5)	895 (129.8)	930 (134.9)	949 (137.7)	990 (143.6)	4.7	-
			B42766	856 (124.2)	878 (127.3)	911 (132.1)	1010 (146.5)	1035 (150.1)	1074 (155.8)	6.8)	-
	AC-C-CCG	"	D36401A	778 (112.9)	805 (116.7)	839 (121.7)	875 (126.9)	904 (131.1)	931 (135.0)	5.2	-
			C46251B	809 (117.3)	836 (121.2)	872 (126.4)	869 (126.0)	898 (130.2)	936 (135.8)	3.0	-
	AC-C	1014	B47660A	667 (96.7)	681 (98.8)	712 (103.2)	695 (100.8)	710 (103.0)	741 (107.5)	2.5	-
		"	A47660B	669 (97.0)	683 (99.0)	712 (103.3)	707 (102.6)	722 (104.7)	754 (109.3)	3.5	-
		1000	C32765	734 (106.5)	749 (108.7)	782 (113.4)	756 (109.7)	772 (112.0)	805 (116.8)	2.5	-
		"	A26159B	745 (108.0)	760 (110.3)	795 (115.3)	778 (112.8)	794 (115.2)	830 (120.4)	3.9	-

B. Test at 649C (1200F)

Std Size	SM-U	None	-	-	823 (119.4)	-	-	1055 (153.0)	-	6.0	5.9
	SM-C	"	-	820 (119.0)	829 (120.2)	845 (122.6)	1073 (155.6)	1084 (157.2)	1105 (160.3)	10.0	11.1

C. Test at 871C (1600F)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	-	654 (94.8)	-	-	796 (115.5)	-	5.0	4.2
	SM-C	"	-	623 (90.4)	629 (91.3)	642 (93.1)	765 (111.0)	774 (112.2)	788 (114.3)	6.0	4.4
0.038 (0.015)	AC-U	"	1	-	584 (84.7)	-	-	657 (95.3)	-	1.8	-
	AC-C	"	2A	474 (68.8)	538 (78.0)	601 (87.2)	494 (71.7)	561 (81.3)	627 (90.9)	1.1	-
0.075 (0.030)	AC-U	"	A41376B	-	617 (89.5)	-	-	735 (106.6)	-	4.9	-
			A17658A	-	641 (93.0)	-	-	741 (107.5)	-	4.0	-
			C11375	-	647 (93.8)	-	-	728 (105.6)	-	4.9	-
			B272772C	-	719 (104.3)	-	-	748 (108.5)	-	4.4	-
	AC-C	"	B11376B	476 (69.1)	514 (74.6)	578 (83.9)	572 (82.9)	617 (89.5)	694 (100.6)	3.2	-
			C41374B	611 (88.6)	649 (94.2)	752 (109.0)	621 (90.0)	660 (95.7)	763 (110.7)	1.5*	-
			A32772B	617 (89.5)	640 (92.8)	700 (101.5)	726 (105.3)	752 (109.0)	823 (119.3)	4.2	-
			A229354A	629 (91.3)	665 (96.4)	708 (102.7)	676 (98.1)	714 (103.5)	760 (110.3)	2.4	-
	"	822	A11377	439 (63.6)	465 (67.5)	544 (78.9)	439 (63.6)	465 (67.5)	544 (78.9)	0.9*	-
		"	D31376A	464 (67.3)	500 (72.5)	560 (81.2)	486 (70.5)	524 (76.0)	586 (85.0)	1.3	-
		1040	B229354	518 (75.2)	554 (80.3)	589 (85.4)	518 (75.2)	554 (80.3)	589 (85.4)	0.8	-
		1000	C32773A	631 (91.5)	657 (95.3)	728 (105.6)	631 (91.5)	657 (95.3)	728 (105.6)	0.6	-
	SM-U	None	A229354B	-	567 (82.2)	-	-	637 (92.4)	-	6.0	-
			B129353A	-	641 (93.0)	-	-	722 (104.7)	-	8.3	-
			C16252B	-	659 (95.6)	-	-	737 (106.9)	-	5.9	-
	SM-C	"	A329354A	479 (69.4)	507 (73.6)	555 (80.5)	574 (83.3)	609 (88.3)	666 (96.6)	2.5*	-
			A429354B	578 (83.8)	613 (88.9)	663 (96.2)	633 (91.8)	685 (97.4)	727 (105.4)	4.0*	-
			A42773A	591 (85.7)	618 (89.6)	694 (100.6)	673 (97.6)	704 (102.1)	789 (114.5)	2.9*	-
	"	1040	D17658	434 (63.0)	461 (66.8)	504 (73.1)	436 (63.2)	462 (67.0)	505 (73.3)	0.6*	-
			C27658A	538 (78.0)	564 (81.8)	627 (91.0)	565 (81.9)	592 (85.9)	658 (95.5)	1.1*	-
	SM-C-E-SM	906	D22777B	-	-	-	-	522 (75.7)	-	1.2*	-
			A32772A	-	510 (74.0)	-	-	544 (78.9)	-	1.3	-
			C42773A	-	524 (76.0)	-	-	552 (80.1)	-	0.9*	-

C. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C-E-SM-C	906	D22771	270 (39.2)	305 (44.2)	334 (48.4)	270 (39.2)	305 (44.2)	334 (48.4)	0.7	-
			C32776	365 (53.0)	417 (60.5)	463 (67.2)	369 (53.5)	421 (61.0)	467 (67.8)	0.7	-
			A16252A	525 (76.2)	580 (84.1)	625 (90.6)	525 (76.2)	580 (84.1)	625 (90.6)	1.0	-
	SM-C-E-SM-C-E	906/857	A12780	183 (26.5)	203 (29.5)	221 (32.0)	183 (26.5)	203 (29.5)	221 (32.0)	0.0*	-
			A32779A	221 (32.0)	252 (36.6)	279 (40.5)	221 (32.0)	252 (36.6)	279 (40.5)	0.4*	-
			D32776	283 (41.0)	315 (45.7)	342 (49.6)	286 (41.5)	319 (46.2)	346 (50.2)	0.7	-
0.15 (0.060)	AC-U	None	D32764B	-	584 (84.7)	-	-	716 (103.8)	-	3.7	-
			B12767B	-	632 (91.6)	-	-	732 (106.2)	-	6.2	-
			A17660A	-	665 (96.4)	-	-	740 (107.4)	-	3.5	-
			C36401A	-	665 (96.4)	-	-	774 (112.2)	-	5.0	-
	AC-U CCG	"	B46401B	-	638 (92.6)	-	-	738 (107.0)	-	6.9	-
	AC-C	"	A47661	563 (81.6)	575 (83.4)	602 (87.3)	650 (94.3)	665 (96.4)	694 (100.8)	1.5*	-
			B37660B	609 (88.3)	621 (90.1)	648 (94.0)	707 (102.6)	722 (104.7)	753 (109.2)	3.5	-
			A22766	617 (89.5)	630 (91.4)	657 (95.3)	726 (105.3)	741 (107.5)	773 (112.1)	3.3	-
			C22769	619 (89.8)	632 (91.6)	656 (95.2)	718 (104.2)	733 (106.3)	762 (110.5)	4.2	-
	AC-C-CCG	"	C36401B	660 (95.7)	681 (98.8)	714 (103.5)	745 (108.0)	769 (111.5)	805 (116.7)	5.4	-
	AC-C	1000	A42766	600 (87.0)	612 (88.8)	638 (92.5)	610 (88.5)	623 (90.3)	649 (94.1)	2.0*	-
		"	D16401B	600 (87.0)	612 (88.8)	638 (92.5)	623 (90.4)	637 (92.4)	665 (96.5)	1.5	-
		1014	D27660B	606 (87.9)	620 (89.9)	648 (94.0)	606 (87.9)	620 (89.9)	648 (94.0)	1.6	-
		"	C17661	621 (90.1)	635 (92.1)	663 (96.2)	621 (90.1)	635 (92.1)	663 (96.2)	1.2	-

D. Test at 982C (1800F)

Std Size	SM-U	None	-	-	345 (50.1)	-	-	467 (67.0)	-	5.0	2.4
	SM-C	"	-	404 (58.6)	408 (59.2)	416 (60.4)	507 (73.6)	513 (74.4)	523 (75.8)	2.0	2.6
0.075 (0.030)	AC-U	"	C21376A	-	320 (46.4)	-	-	414 (60.0)	-	3.8	-
			C32771B	-	340 (49.3)	-	-	483 (70.0)	-	5.3	-
			B11375B	-	365 (52.9)	-	-	455 (66.0)	-	4.0	-
			D129354A	-	401 (58.2)	-	-	458 (66.4)	-	6.2	-

D. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi) (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.075 (0.030)	AC-C	None	A41374	299 (43.4)	322 (46.7)	359 (52.1)	341 (49.4)	366 (53.1)	409 (59.3)	2.9*	-
			D41375	330 (47.9)	354 (51.4)	403 (58.5)	365 (52.9)	392 (56.8)	445 (64.6)	2.0	-
			C31376	349 (50.6)	370 (53.7)	427 (62.0)	422 (61.2)	448 (65.0)	517 (75.0)	2.2*	-
			B12774B	399 (57.9)	414 (60.1)	456 (66.2)	481 (69.7)	499 (72.4)	550 (79.7)	2.9*	-
	"	822	C21376B	298 (43.2)	321 (46.6)	368 (53.4)	303 (43.9)	326 (47.3)	374 (54.2)	1.4*	-
		636	B12771A	319 (46.2)	330 (47.9)	362 (52.5)	358 (51.9)	371 (53.8)	407 (59.0)	1.3	-
		822	A31377	333 (48.3)	353 (51.2)	399 (57.9)	372 (53.9)	394 (57.1)	445 (64.6)	2.5*	-
		1000	B37658B	361 (52.3)	375 (54.4)	413 (59.9)	414 (60.1)	431 (62.5)	475 (68.9)	1.7	-
	SM-U	None	C429354	-	364 (52.8)	-	-	430 (62.3)	-	3.9	-
			A12777B	-	387 (56.2)	-	-	500 (72.5)	-	4.3	-
			D42773A	-	414 (60.0)	-	-	457 (66.3)	-	3.4	-
	SM-C	"	B22774	307 (44.5)	327 (47.4)	355 (51.5)	383 (55.6)	408 (59.2)	443 (64.3)	2.2*	-
			D129354A	334 (48.5)	354 (51.4)	387 (56.2)	396 (57.4)	420 (60.9)	459 (66.6)	2.2	-
			D32777	372 (53.9)	394 (57.2)	431 (62.5)	459 (66.5)	486 (70.5)	532 (77.1)	4.0	-
	"	1040	D47658A	272 (39.5)	287 (41.6)	322 (46.7)	272 (39.5)	287 (41.6)	322 (46.7)	1.4*	-
			A47658	330 (47.9)	350 (50.8)	393 (57.0)	335 (48.6)	355 (51.5)	399 (57.8)	1.2*	-
	SM-C-E-SM	906	D12773B	-	303 (44.0)	-	-	402 (58.3)	-	1.5*	-
			C12772B	-	334 (48.4)	-	-	381 (55.3)	-	1.4*	-
			A42777†	-	493†(71.5)	-	-	556†(80.6)	-	1.6	-
	SM-C-E-SM-C	"	A12778	211 (30.6)	242 (35.1)	299 (43.3)	252 (36.5)	290 (42.0)	356 (51.6)	1.2	-
			B22773B	270 (39.2)	303 (44.0)	332 (48.1)	312 (45.2)	350 (50.8)	383 (55.5)	1.5	-
			B12780B	296 (43.0)	325 (47.1)	348 (50.4)	319 (46.3)	349 (50.7)	374 (54.3)	1.6*	-
	SM-C-E-SM-C-E	906/857	A32771	Failed in setting up						-	-
			D22774A	212 (30.8)	234 (34.0)	265 (38.5)	224 (32.5)	248 (35.9)	280 (40.6)	1.4*	-
			C12777B	225 (32.7)	247 (35.8)	269 (39.0)	233 (33.8)	255 (37.0)	279 (40.4)	1.0*	-
0.15 (0.060)	AC-U	None	B47660B	-	376 (54.6)	-	-	476 (69.0)	-	2.7	-
			A26401B	-	390 (56.6)	-	-	501 (72.6)	-	5.5	-
			D37660A	-	409 (59.3)	-	-	485 (70.3)	-	4.1	-
			C32766	-	420 (60.9)	-	-	480 (69.6)	-	3.6	-
	AC-C	"	C47660B	342 (49.6)	350 (50.7)	367 (53.2)	421 (61.0)	430 (62.4)	451 (65.4	2.1	-
			A46159	371 (53.8)	379 (54.9)	396 (57.4)	441 (64.0)	451 (65.4)	471 (68.3)	3.0	-
			B12767A	379 (54.9)	386 (56.0)	403 (58.4)	469 (68.0)	479 (69.4)	499 (72.4)	3.1*	-

D. (Cont.)

Specimen Thickness cm (inch)	Spec. Cond. ††	Expos. Time hrs.	Specimen Number	0.2% Y.S. MN/m² (ksi) (1)	0.2% Y.S. MN/m² (ksi) (2)	0.2% Y.S. MN/m² (ksi (3)	U.T.S. MN/m² (ksi) (1)	U.T.S. MN/m² (ksi) (2)	U.T.S. MN/m² (ksi) (3)	Elong. %	R.A. %
0.15 (0.060)	AC-C	1014	A37661	349 (50.3)	354 (51.4)	370 (53.6)	430 (62.3)	439 (63.6)	458 (66.4)	2.8	-
		"	B17660	374 (54.3)	383 (55.5)	401 (58.1)	420 (60.9)	430 (62.3)	450 (65.2)	2.1	-
		1000	C16251	395 (57.3)	403 (58.5)	422 (61.2)	472 (68.5)	483 (70.0)	504 (73.1)	4.0	-
		"	B32767	410 (59.5)	419 (60.7)	437 (63.4)	440 (63.8)	449 (65.1)	468 (67.9)	2.5*	-

† Mistakenly tested at 899C (1650F)

All exposures at 982C (1800F)

* Specimens failed at or near end of gage length.

†† Specimen condition: AC = As cast, SM = Surface machined, U = Uncoated, C = Coated

(1) Strength based on external specimen dimensions including coating.
(2) " " " original specimen dimensions before coating.
(3) " " " unaffected remaining metal thickness (below coating additive layer and diffusion zone).

Table XIII Stress Rupture Test Results: Rene 120 Heat B325

A. Test at 760C (1400F), 634 MN/m² (92,000 psi)(2)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	86.5	-	-	-	3.3
		"	-	150.7	-	-	1.9	3.0
	SM-C	"	-	171.6	153	236	1.3*	5.2
0.075 (0.030)	AC-U	"	B18581B	25.4	-	-	1.9	-
			?A28578B	72.0	-	-	3.3	-
			?A28581A	146.0	-	-	3.2	-
			D38581B	147.0	-	-	3.2	-
	AC-C	"	?B38576A	† 1.1	-	-	0.7*	-
			?A28577B	14.5	-	-	1.4	-
			?C28579	27.3	-	-	1.9	-
	"	997	?C38581A	7.3	4	48	1.1*	-
			C28576	9.3	5	38	0.7*	-
			?A38577A	17.1	8	92	1.9	-
			B48579	19.8	12	140	2.8	-
0.15 (0.060)	AC-U	None	C28240A	81.0	-	-	2.0*	-
			A28240A	105.4	-	-	2.0	-
			?B18241B	139.5	-	-	3.0*	-
			B28236	143.1	-	-	3.0	-
	AC-C	"	D48237B	29.1	20	60	1.9*	-
			?C28237A	48.0	33	105	1.4*	-
			?A48241A	49.3	33	115	1.9	-
			A28241A	59.2	42	149	2.3	-
	"	993	C48235B	0.1	0.1	0.2	0.5	-
			?C28237B	0.1	0.1	0.3	1.4*	-
			?B18241A	0.3	0.2	1	0.9	-
			A38240A	0.5	0.4	1	0.9	-

† Some porosity at fracture

B. Test at 871C (1600F), 379 MN/m² (55,000 psi)[2]

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	138.9 †	-	-	1.9	2.8
		"	-	182.4	-	-	3.8	4.8
	SM-C	"	-	38.8	36	47	2.3*	2.3
0.075 (0.030)	AC-U	"	B18578B	7.2	-	-	1.4*	-
			C18576	26.7	-	-	2.4*	-
			?B28579A	34.7	-	-	2.4*	-
			A38581B	67.7	-	-	3.0	-
	AC-C	"	?D28581A	2.2	1	6	0.8*	-
			?A38577B	7.4	5	22	1.1	-
			?B38579A	8.5	5	25	1.2*	-
			?A28581B	28.4	20	100	1.6	-
	"	997	?A48581B	Failed on loading			0.5	-
			C48577A	2.4	2	8	1.4	-
			?B38576B	6.0	4	17	1.0	-
			A18579	6.3	4	14	2.0	-
			?D48578B	14.4	11	28	0.9	-
0.15 (0.060)	AC-U	None	B38241	4.7	-	-	2.0*	-
			?B28237B	33.0	-	-	2.0	-
			C38240B	56.2	-	-	4.0	-
			?A48240A	65.2	-	-	2.0*	-
	AC-C	"	A38236B	1.2 †	1	2	1.1*	-
			B48241	5.2	4	9	1.7*	-
			C38237B	18.7	14	30	1.7	-
	"	993	C28240B	0.4	0.3	0.7	0.9	-
			?D18241A	0.7	0.6	1	0.9	-
			?B38237B	2.0	2	3	1.4	-
			?A18237B	7.4	6	13	0.9	-

† Extrapolated from test run at 413 MN/m² (60,000 psi).

† Excessive taper in specimen thickness.

C. Test at 982C (1800F), 172 MN/m² (25,000 psi)[2]

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	102.7	-	-	3.4	5.3
			-	134.4 †	-	-	3.4	3.8
	SM-C	"	-	73.6	68	84	2.6*	2.2
0.075 (0.030)	AC-U	"	C48578	38.9	-	-	1.9*	-
			A18577B	40.8	-	-	2.4	-
			?D38579	57.7	-	-	3.6	-
			B38579B	89.5	-	-	2.3	-
	AC-C	"	?A18578A	4.1	3	9	3.0	-
			A18581B	14.2	11	28	2.3	-
			?D18581A	18.7	14	40	2.4	-
			?B28577A	37.9	31	90	3.0	-
	"	997	D38576	7.9	6	17	1.9	-
			?D18577	15.3	13	32	3.3	-
			C48581	15.6	13	31	4.5	-
			?A28578A	30.5	24	57	3.2	-
0.15 (0.060)	AC-U	None	?D18237B	50.9	-	-	3.6	-
			?B18240A	59.7	-	-	4.2	-
			A38236A	71.3	-	-	4.2	-
			C38241B	78.9	-	-	3.0	-
	AC-C	"	?D38241B	42.0	36	56	3.1*	-
			C18236	45.6	40	62	3.1	-
			?A28237A	70.5	60	93	3.9	-
	"	993	D48237A	4.3	4	7	1.4*	-
			?B48240A	21.0	18	32	2.3	-
			?B28241A	50.0 †	43	76	2.7	-
			?A38241A	59.5	50	91	4.3	-

† Extrapolated from tests run at slightly different stresses.

D. Test at 1093C (2000F), 55 MN/m² (8,000 psi)(2)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	181.3	-	-	3.1	0.8
	SM-C	"	-	92.4	88	102	1.0	1.0
			-	248.0	236	273	3.0	3.0
0.075 (0.030)	AC-U	"	?C38579A	16.6	-	-	3.4	-
			C18579	33.0	-	-	3.0	-
			B28577B	159.6	-	-	5.3	-
			A38578B	196.0	-	-	5.1	-
	AC-C	"	A28579B	19.8	17	34	3.7	-
			?D48577	37.0	31	56	3.6	-
			?A18581A	40.7	35	67	3.8	-
			B18581A	66.8	54	107	4.1	-
	"	977	?B18578A	18.6	15	26	3.5	-
			?C18581B	46.8	37	68	3.2	-
			?A48576	63.8	49	100	5.5	-
			?D38577	83.6	67	132	5.1	-
0.15 (0.060)	AC-U	None	?B28241B	46.7	-	-	3.2	-
			D48240B	60.4	-	-	3.9	-
			A38237A	67.6	-	-	2.8	-
			C48235A	111.3	-	-	4.1	-
	AC-C	"	A48241B	66.8	60	83	2.9	-
			?C28241A	69.4	62	92	3.7	-
			?C48240A	78.8	71	95	4.6	-
	"	993	A18241B	23.8	21	32	4.8	-
			?D38237B	40.3	36	53	2.8	-
			C28241B	132.8	119	167	4.1	-
			?B28240B	137.0	122	183	4.3	-

All exposures at 982C (1800F)

†† Specimen condition: AC = As cast, SM = Surface machined, U = Uncoated, C = Coated.

* Specimens failed at or near end of gage length.

(2) Life based on stress calculated using original metal thickness before coating (test load for this stress).

(1) Life based on stress calculated using overall thickness, including coating, extrapolated from (2).

(3) Life based on stress calculated using unaffected remaining metal thickness, extrapolated from (2).

Table XIV Stress Rupture Test Results: Rene 120 Heat B415

A. Test at 760C (1400F), 634 MN/m² (92,000 psi)(2)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size 0.64 (0.25) diameter	SM-U	None	-	42.9	-	-	1.8*	7.4
			-	128.2	-	-	2.3	6.2
			-	142.6	-	-	2.0	4.0
	SM-C	"	-	41.6	36.5	53.3	4.0	4.0
0.038 (0.015)	AC-U	"	10	0 †	-	-	-†	-
	AC-C	"	4	0 †	-	-	-†	-
0.075 (0.030)	AC-U	"	D31375B	0.4	-	-	1.8*	-
			C11374B	0.3†	-	-	2.3	-
			D27658A	58.1	-	-	4.0	-
			B12773B	71.1	-	-	4.4	-
	AC-C	"	C41375A	0.1	0.1	9.5	1.0	-
			C12774B	0.2	0.1	0.5	0.8	-
			D31376B	3.2	2	20	1.4	-
			B22777A	22.4	15	66	2.5	-
	"	822	A11375A	Failed on Loading			0.6	-
		"	B31376	"	"	"	0.5	-
		"	C41376A	"	"	"	0.5	-
		1000	C129354A	0.9	0.4	2	2.9	-
	SM-U	None	D329354B	10.7	-	-	1.7	-
			A22771A	22.0	-	-	1.6	-
			A429354A	31.1	-	-	3.9	-
	SM-C	"	D36252A	1.0	0.5	4	2.3	-
			D12772	7.7	4	28	2.7	-
			A129354	8.0	4	26	2.5	-
	"	1040	C36252B	0.5	0.3	2	2.3	-
			B27658B	2.9	2	11	2.0	-
			C17658A	7.3	4	23	1.0	-
	SM-C-E-SM	906	C32771A	Failed on Loading			1.1*	-
			B12773A	0.05†	-	-	- †	-
			D42777	0.1	-	-	1.3	-
	SM-C-E-SM-C	"	D32771B	Failed on Loading			0.5	-
			B22773A	"	"	"	0.7*	-
			A22774	"	"	"	0.9*	-
	SM-C-E-SM-C-E	906/857	B22772A	"	"	"	0.2*	-
			B42780	"	"	"	0.3	-
			B42773	"	"	" †	- †	-

A. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.15 (0.060)	AC-U	None	D22767	34.8	-	-	~1.5	-
			A22764	66.9	-	-	"	-
			B47661	118.7	-	-	"	-
			C46159	122.9	-	-	"	-
	AC-C	"	A42764B	8.3	6	14	1.3	-
			D12767C	12.8	10	21	1.7	-
			A17660B	18.3	14	31	1.8	-
			B16401B	60.0	46	102	1.9	-
	"	1000	D12766A	Failed on Loading			0.9*	-
			A12765	"	"	"	1.3*	-
			B36401A	0.3	0.2	0.5	0.9	-
			C22767B	1.5	1	3	0.9	-

B. Test at 871C (1600F), 414 MN/m^2 (60,000 psi)

Std Size	SM-U	None	-	75.1	-	-	4.0	-
	SM-C	"	-	50.0	46.5	64	2.0	2.0

C. Test at 871C (1600F), 310 MN/m^2 (45,000 psi)

Std Size	SM-U	None	-	266.1	-	-	1.9*	3.8
			-	460.3	-	-	3.8	4.8
	SM-C	"	-	654.0	602	732	4.0	4.0
0.075 (0.030)	AC-U	"	B42777B	2.9†	-	-	0.7	-
			A11375B	42.5	-	-	2.6	-
			B21376	42.5	-	-	2.0	-
			C42773B	62.4	-	-	4.1	-
	AC-C	"	D31377A	4.1	3	10	2.1	-
			A37658B	16.4	13	33	1.2*	-
			B41375B	21.1	14	56	1.7	-
			D32771A	85.3	68	169	2.3	-
	"	822	D41376	3.1	2	8	1.5	-
		"	C41374A	3.4	2	9	1.2	-
		"	C31377	12.1	9	32	2.2	-
		1000	C22772B	23.0	19	43	1.5	-

C. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.075 (0.030)	SM-U	None	D1277	0.2†	-	-	1.1	-
			C32773B	0.5	-	-	2.1	-
			D129354B	38.9	-	-	3.1	-
	SM-C	"	C129354B	16.9	12	27	1.9	-
			C22774B	27 †	18	62	0.9	-
			B47658A	35 †	21	88	0.7*	-
	"	1040	D37658	10.6†	8	24	2.3	-
			B47658B	11.2†	8	22	2.0	-
			A17659A	14.2†	11	30	1.7*	-
	SM-C-E-SM	906	C42777B	1.0†	-	-	0.2†	-
			D22772	6.6†	-	-	0.5†	-
			A32776	31.4	-	-	3.0*	-
	SM-C-E-SM-C	"	D12773A	1.0	0.5	2	1.2	-
			A22772	1.9	1	4	1.3*	-
			B22777B	3.6	2	6	1.3	-
	SM-C-E-SM-C-E	906/857	C32774B	Failed on Loading			0.2	-
			C12771	0.1†	0.05†	0.2†	0.4†	-
			D32773A	0.4	0.2	0.8	2.2*	-
0.15 (0.060)	AC-U	None	A47660A	140.4	-	-	2.0*	-
			C22765	185.1	-	-	2.3	-
			B26251	234.4	-	-	1.2	-
			A27661	257.2	-	-	3.0	-
	AC-U CCG	"	D26401A	135.3	-	-	4.2	-
			B36251B	190.9	-	-	3.4	-
	AC-C	"	A36401	65.6	58	89	1.2	-
			B17661	112.9	100	150	-	-
			C22767A	158.6	141	208	1.9	-
			D42764	183.7	163	241	3.3	-
	AC-C CCG	"	D16401A	31.9†	26†	42†	-	-
			B46159B	112.1†	96	152	2.4	-
	AC-C	1000	D12767B	23.9	19	31	0.9*	-
			B42765	35.6	29	47	0.9	-
			A16401A	40.0	32	52	1.0*	-
			C32764B	111.7	90	146	2.7*	-

D. Test at 982C (1800F), 207 MN/m^2 (30,000 psi)

Std Size	SM-U	None	-	51.1	-	-	4.0	4.0
	SM-C	"	-	<48.0	<46.5	<52	3.0	2.0

E. Test at 982C (1800F), 145 MN/m^2 (21,000 psi)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
Std Size	SM-U	None	-	280.0†	-	-	3.2	4.3
			-	399.3	-	-	2.9	3.8
	SM-C	"	-	494.6	465	539	5.0	5.0
0.038 (0.015)	AC-U	"	2*	1.2	-	-	0.5	-
	AC-C	"	6	1.8	1	3	0.7	-
0.075 (0.030)	AC-U	"	B21377	37.9	-	-	2.5	-
			C31375	44.6	-	-	2.2	-
			B129353B	98.1	-	-	3.0	-
			C127772A	100.2†	-	-	2.4	-
	AC-C	"	C31374B	27.5	19	49	3.3	-
			A21376B	30.5	23	63	2.5	-
			D32773B	59.7	50	93	4.8	-
			D47658B	72.3	61	117	2.8*	-
	"	822	D21376B	15.4	12	29	3.2	-
		"	B41374	18.6	14	35	5.5	-
		"	A41376A	19.3	15	38	4.0	-
		1000	C22777A	54.7	47	82	4.9	-
	SM-U	None	A42778	66.9	-	-	3.0	-
			D22774B	70.8†	-	-	2.1	-
			A329354B	98.3	-	-	2.6	-
	SM-C	"	C22780	15.5	12	24	4.8	-
			D27658B	40 †	32	75	1.8*	-
			A12776	46 †	36	80	2.4	-
	"	1040	C47858	6.5	5	12	5.8	-
		"	B37858A	29.2	21	43	8.2	-
		1014	B36252B	65.8	55	107	7.3	-
	SM-C-E-SM	906	C12774A	10.6	-	-	2.4	-
			D32772B	29.2	-	-	2.8*	-
			A42776A	88.3	-	-	4.4	-
	SM-C-E-SM-C	"	A12779	2.9	2	5	1.6*	-
			D42774A	6.6	4	10	2.7	-
			B42772B	8.5	5	13	2.8	-
	SM-C-E-SM-C-E	906/857	D12776	0.7	0.5	1	3.4	-
			C42773C	1.6	1	3	6.5	-
			A12773	2.8	2	5	9.1	-

E. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
015 (0.060)	AC-U	None	D17660A	85.8	-	-	6.9	-
			C42767	124.3	-	-	5.9	-
			B36401B	160.7	-	-	6.2	-
			A42765A	165.3	-	-	5.6	-
	AC-C	"	A37660	158.7	143	197	3.3*	-
			A42765B	163.2	150	197	3.3	-
			D27660A	180.4	166	218	3.3*	-
			C32767A	188.8	166	217	4.1	-
	"	1000	B32769	52.8	49	64	2.8	-
		1014	A27660A	76.9	69	95	3.6	-
		1014	D47660	95.2	86	116	4.2	-
		1000	D36159	95.6	88	118	4.4	-

F. Test at 1093C (2000F), 55 MN/m² (8,000 psi)

Std Size	SM-U	None	-	188.8	-	-	3.2	19.6
	SM-C	"	-	158.7	154	172	3.1	5.7
			-	382.4	369	413	6.0	3.0
0.075 (0.030)	AC-U	"	A21375	13.5	-	-	3.6	-
			B41376	16.0	-	-	2.4	-
			A22771B	40.2	-	-	3.9	-
			C229354B	41.8	-	-	2.7	-
	AC-C	"	B11374	10.6	8	18	6.0	-
			C229354A	43.3	35	57	3.0	-
			A42773B	60.8	52	87	7.8	-
			D32772A	91.4	79	131	7.3	-
	"	822	C31374A	15.6	12	27	4.4	-
		"	B31377B	31.6	24	51	5.9	-
		1040	D429354B	34.0	28	48	3.7	-
		1000	C22774A	74.4	64	107	3.2	-
	SM-U	None	B42778	25.3	-	-	3.3	-
			A37658A	28.1	-	-	2.8	-
			C42776	47.9	-	-	5.4	-
	SM-C	"	C32777B	21.0	17	31	4.6	-
			C42780	26.3	22	39	6.0	-
			A17559B	50.5	42	78	3.7	-
	"	1040	A17658B	33.4	28	51	3.7*	-
		906	D42771A	38.6	33	59	6.9	-
		"	A47659A	40.3	34	61	2.4*	-

F. (Cont.)

Specimen Thickness cm (inch)	Specimen Condition ††	Exposure Time hrs.	Specimen Number	Life, hrs (2)	Life, hrs (1)	Life, hrs (3)	Elong. %	R.A. %
0.075 (0.030)	SM-C-E-SM	906	B42774A	15.4	-	-	1.7*	-
			A42772	19.1	-	-	1.7	-
			C22777B	19.2	-	-	2.6	-
	SM-C-E-SM-C	"	C22771	5.8	3	9	4.7	-
			A22773	6.2	3	9	3.9	-
			B42776	9.9	7	15	3.0	-
	SM-C-E-SM-C-E	906/857	B12774A	2.5	1	4	6.1	-
			C22772A	4.7	3	7	3.7	-
			B32777	6.0	4	9	4.6	-
0.15 (0.060)	AC-U	None	C12769	41.3	-	-	2.7	-
			A16251A	55.0	-	-	4.6	-
			B12766B	69.6	-	-	3.5	-
			A27660B	183.5	-	-	3.9	-
	AC-U CCG	"	C26401A	78.4	-	-	4.2	-
			A26159A	88.8	-	-	3.6*	-
	AC-C	"	C12765	26.7	25	32	2.5	-
			A12769	51.6	47	60	4.2	-
			B46401A	55.2	51	66	2.8	-
			D37660B	68.5	63	82	3.4	-
	AC-C CCG	"	D46401A	89.5	77	105	3.8	-
			B26401A	127.2	115	154	4.2	-
	AC-C	1000	B37660A	66.4	61	80	2.7	-
			C27660B	83.2	76	100	3.8	-
			B12768	97.7	90	115	-	-
			D17660B	116.6	107	140	3.9	-

† Tested at slightly different stress. Life extrapolated to indicated stress.

†† Specimen Condition: AC = As cast, SM = Surface machined: removed 0.05 to 0.07 mm (0.0025 inch) for initial SM on 0.075 cm specimens (each side); 0.12 to 0.13 mm (0.005 inch) for SM after exposure on 0.075 cm specimens (each side) and on radius of standard size bars, U = Uncoated, C = Coated, E = Exposed, CCG = Coarse columnar grained

Exposure temperature = 982C (1800F)

* Specimens failed at or near end of gage length.
† " " in grip section. True life should be higher.

(2) Life based on stress calculated using original metal thickness before coating (test load for this stress).

(1) Life based on stress calculated using overall thickness, including coating, extrapolated from (2).

(3) Life based on stress calculated using unaffected remaining metal thickness, extrapolated from (2).

Table XV Average Stress Rupture Properties: Rene 120

A. Test at 760C (1400F), 634 MN/m² (92,000 psi)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B325				Heat B415			
		Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.
Std Size	SM-U/C	130.8	1.5*	-	3	75.6	2.5*	-	4
0.075 (0.030)	AC-U	79.2	2.9	0.0721 (0.0284)	4	† 43.0	3.1	0.0714 (0.0281)	4
	AC-C	19.9	1.7	0.0686 (0.0270)	2	† 4.3	1.4	0.0732 (0.0288)	4
	AC-C-E	12.3	1.6*	0.0706 (0.0278)	4	† 0.2	1.1	0.0686 (0.0270)	4
	SM-U	-	-	-	-	19.4	2.4	0.0645 (0.0254)	3
	SM-C	-	-	-	-	4.0	2.5	0.0645 (0.0254)	3
	SM-C-E	-	-	-	-	† 3.2	1.8	0.0617 (0.0243)	3
	SM-C-E-SM	-	-	-	-	0.1†	1.2*	0.0389 (0.0153)	3
	SM-C-E-SM-C	-	-	-	-	F.O.L.	0.7*	0.0401 (0.0158)	3
	SM-C-E-SM-C-E	-	-	-	-	F.O.L.	0.3*	0.0427 (0.0168)	3
0.15 (0.060)	AC-U	114.3	2.5*	0.1473 (0.0580)	4	76.3	~1.5	0.1496 (0.0589)	4
	AC-C	44.9	1.9*	0.1527 (0.0601)	4	18.5	1.7	0.1473 (0.0580)	4
	AC-C-E	0.2	0.9*	0.1544 (0.0608)	4	0.5	1.0*	0.1514 (0.0596)	4

B. Test at 871C (1600F),

		Stress = 379 MN/m² (55,000 psi)				Stress = 310 MN/m² (45,000 psi)			
Std Size	SM-U/C	99.4	2.7*	-	3	350.0	2.9*	-	2
0.075 (0.030)	AC-U	† 31.6	2.3*	0.0737 (0.0290)	4	† 37.0	2.9	0.0732 (0.0288)	4
	AC-C	7.9	1.2*	0.0724 (0.0285)	4	† 24.2	1.8*	0.0693 (0.0273)	4
	AC-C-E	6.0	1.3	0.0795 (0.0313)	4	7.4	1.6	0.0711 (0.0280)	4
	SM-U	-	-	-	-	† 13.2	2.1	0.0653 (0.0257)	3
	SM-C	-	-	-	-	25.2	1.2*	0.0645 (0.0254)	3

B. (Cont.)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B325				Heat B415			
		Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.
0.075 (0.030)	SM-C-E	-	-	-	-	11.9	2.0*	0.0579 (0.0228)	3
	SM-C-E-SM	-	-	-	-	† 9.9†	3.1	0.0470 (0.0185)	3
	SM-C-E-SM-C	-	-	-	-	1.9	1.3*	0.0411 (0.0162)	3
	SM-C-E-SM-C-E	-	-	-	-	0.2†	1.2*	0.0424 (0.0167)	3
0.15 (0.060)	AC-U	† 38.3	2.5*	0.1461 (0.0575)	4	199.0	2.1	0.1496 (0.0589)	4
	AC-C	9.9	1.7*	0.1511 (0.0595)	2	121.2	2.1	0.1499 (0.0590)	4
	AC-C-E	1.4	1.0	0.1661 (0.0654)	4	44.2	1.4*	0.1527 (0.0601)	4

C. Test at 982C (1800F)

		Stress = 172 MN/m² (25,000 psi)				Stress = 145 MN/m² (21,000 psi)			
Std Size	SM-U/C	100.5	3.1*	-	3	381.0	3.7	-	3
0.065 (0.030)	AC-U	53.5	2.6*	0.0747 (0.0294)	4	63.9	2.5	0.0820 (0.0323)	4
	AC-C	† 17.2	2.7	0.0739 (0.0291)	4	43.6	3.4*	0.0686 (0.0270)	4
	AC-C-E	15.5	3.2	0.0711 (0.0280)	4	23.5	4.4	0.0744 (0.0293)	4
	SM-U	-	-	-	-	77.5	2.6	0.0653 (0.0257)	3
	SM-C	-	-	-	-	30.6	3.0*	0.0638 (0.0251)	3
	SM-C-E	-	-	-	-	23.2	7.1	0.0615 (0.0242)	3
	SM-C-E-SM	-	-	-	-	30.1	3.2*	0.0528 (0.0208)	3
	SM-C-E-SM-C	-	-	-	-	5.5	2.4*	0.0424 (0.0167)	3
	SM-C-E-SM-C-E	-	-	-	-	1.5	6.3	0.0427 (0.0168)	3
0.14 (0.060)	AC-U	64.3	3.8	0.1511 (0.0595)	4	129.7	6.2	0.1514 (0.0596)	4
	AC-C	51.3	3.3*	0.1633 (0.0643)	3	172.3	3.5*	0.1529 (0.0602)	4
	AC-C-E	† 30.8	2.7*	0.1511 (010595)	4	78.0	3.8	0.1425 (0.0561)	4

D. Test at 1093C (2000F), 55 MN/m² (8,000 psi)

Nominal Thickness cm (inch)	Specimen Condition ††	Heat B325				Heat B415			
		Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.	Average Life hrs	Av'g. Elong. %	Average Thickness cm (inch)	No. of Spec.
Std Size	SM-U/C	168.8	2.4	-	3	225.4	4.1	-	3
0.075 (0.030)	AC-U	64.3	4.2	0.0737 (0.0290)	4	24.3	3.2	0.0749 (0.0295)	4
	AC-C	37.6	3.8	0.0762 (0.0300)	4	40.0	6.0	0.0724 (0.0285)	4
	AC-C-E	46.4	4.3	0.0787 (0.0310)	4	33.4	4.3	0.0719 (0.0283)	4
	SM-U	-	-	-	-	32.4	3.8	0.0693 (0.0273)	3
	SM-C	-	-	-	-	30.3	4.8	0.0643 (0.0253)	3
	SM-C-E	-	-	-	-	37.3	4.3*	0.0620 (0.0244)	3
	SM-C-E-SM	-	-	-	-	17.8	2.0*	0.0432 (0.0170)	3
	SM-C-E-SM-C	-	-	-	-	7.1	3.9	0.0419 (0.0165)	3
	SM-C-E-SM-C-E	-	-	-	-	4.1	4.8	0.0424 (0.0167)	3
0.15 (0.060)	AC-U	67.9	3.5	0.1534 (0.0604)	4	73.4	3.7	0.1506 (0.0593)	4
	AC-C	71.5	3.7	0.1643 (0.0647)	3	47.8	3.2	0.1476 (0.0581)	4
	AC-C-E	64.6	4.0	0.1501 (0.0591)	4	89.1	3.5	0.1400 (0.0551)	4

†† Specimen Condition: AC = As cast, SM = Surface Machined (see footnote of Table XIV), U = Uncoated, C = Codep B-1 coated, E = Exposed ~1000 hrs at 982C.

* Specimens failed at or near end of gage length.

↑ " " in grip section. True life should be higher.

Stress rupture lives are logarithmic or log/linear averages (see text), and are based on method 2 for stress calculation. † indicates log/linear average.

Table XVI Mechanical Fatigue Test Results, Rene 120

A. Heat B325

Specimen Condition ††	Exposure Time hrs.	Specimen Number	Reversed Bending Stress MN/m²	(ksi)	Cycles to Failure	Fatigue Strength at 10^7 Cycles MN/m² (ksi)
AC-U	None	?B38578A	427	(62.0)	0.847 x 10^6	
		C44337	361	(52.3)	2.410 "	
		?B38578A	338	(49.0)	4.210 "	
		C44337	300	(43.5)	7.216 "	283 (41.0)
AC-C	"	C28577A	414	(60.0)	0.058 "	
		?D38581A	379	(55.0)	1.329 "	
		C28577A	313	(45.4)	0.376 " *	
		?D38581A	276	(40.0)	18.697 " →	283 (41.0)
"	997	?B28578C	414	(60.0)	0.157 "	
		A48579B	379	(55.0)	0.841 "	
		?B28578C	345	(50.0)	7.049 "	
		A48579B	276	(45.0)	15.015 " →	317 (46.0)

B. Heat B415

AC-U	None	A21377	416	(60.3)	0.497 "	
		A21377	348	(50.5)	1.335 "	
		C41375	276	(45.0)	3.476 "	
		C41375B	269	(39.0)	1.076 "	255 (37.0)
AC-C	"	D31377B	407	(59.0)	0.083 "	
		D31377B	267	(38.7)	3.062 "	
		B11376A	241	(35.0)	15.295 " →	
		B11376A	207	(30.0)	10.689 " →	255 (37.0)
"	822	A21375A	400	(58.0)	0.090 "	
		A21375A	345	(50.0)	0.222 "	
		C11376B	265	(38.5)	5.101 "	
		C11376B	241	(35.0)	12.994 " →	255 (37.0)
SM-C	1040	B17659	425	(61.7)	0.666 "	
		B17659	346	(50.2)	6.089 "	331 (48.0)

All specimens 0.075 cm (0.030 inch) thick, tested in reversed bending. Stress calculated on exterior dimensions.

All exposures at 982C (1800F)

†† Specimen condition: AC = As cast, SM = Surface machined, U = Uncoated, C = Codep B-1 coated.

* Failed at shoulder location.

→ No failure.

Table XVII X-Ray Diffraction Analysis of Surface Phases on Codep B-1 Coated Specimens

Specimen Thickness cm (inch)	Specimen Condition			Spec. No.	Relative Intensity of 3 Strongest Lines and Lattice Parameter of Surface Phases*											Other Phases
	Alloy	Exposure or S/R Test			NiAl				α Al_2O_3			γ - γ'**				
		Temp. °C (°F)	Time hrs		1	2	3	a_o, Å	1	2	3	1	2	3	a_o, Å	
0.075 (0.030)	Rene 80	As coated		7617A4B?	92	8	11	2.887	3	4½	1½	-	-	-	-	-
0.15 (0.060)	"	" "		7534A4A	72	7	11	2.886	3	2½	1	-	-	-	-	-
0.075 (0.030)	"	899 (1650)	997	7620C3	74	2	9	2.877	2½	2	1½	-	-	-	-	-
" "	"	982 (1800)	993	7621A2A	44	1	7	2.873	4	6	3	7	2	1	3.590	-
0.15 (0.060)	"	" "	1013	7539C1A	57	1	7	2.876	3	6	3	7	2	1	3.590	-
0.075 (0.030)	"	1093 (2000)	46.1	7621B4A	40	1	5	2.872	2	3	1½	13	4	1½	3.581	$NiAl_2O_4$
0.15 (0.060)	"	" "	110.4	7538A2A	37	½	4	2.870	2	4	2½	13	4	2	3.581	$NiAl_2O_4$
0.075 (0.030)	Rene 120	As coated		C28577B	95	7	12	2.883	4	4	3	-	-	-	-	-
0.15 (0.060)	"	" "		D18240A	82	4	8	2.884	4	3	2	-	-	-	-	-
0.075 (0.030)	"	982 (1800)	997	C18581A	49	½	5½	2.870	3	4	2	7	2	2	3.590	-
0.15 (0.060)	"	" "	993	C18241A	46	½	5	2.873	3	3½	2	5½	2	2	3.588	-
0.075 (0.030)	"	1093 (2000)	66.8	B18581A	41	½	3	2.873	3	3	2	14	5	5	3.586	$NiAl_2O_4$
0.15 (0.060)	"	" "	78.8	C48240A	35	0	5	2.871	3	3	1½	13	4	5	3.582	$NiAl_2O_4$

All diffraction patterns run on goniometer at the same nominal conditions: Co radiation, Fe filter, 40 kv, 10 ma.

* Three strongest lines listed in order of intensity as shown on ASTM standard identification cards.

** γ-γ' lattice parameter of bare samples: Rene 80 = 3.578 Å (spec. #7534B4A)

Rene 120 = 3.588 Å (avg spec. #B28240A-D48578A)

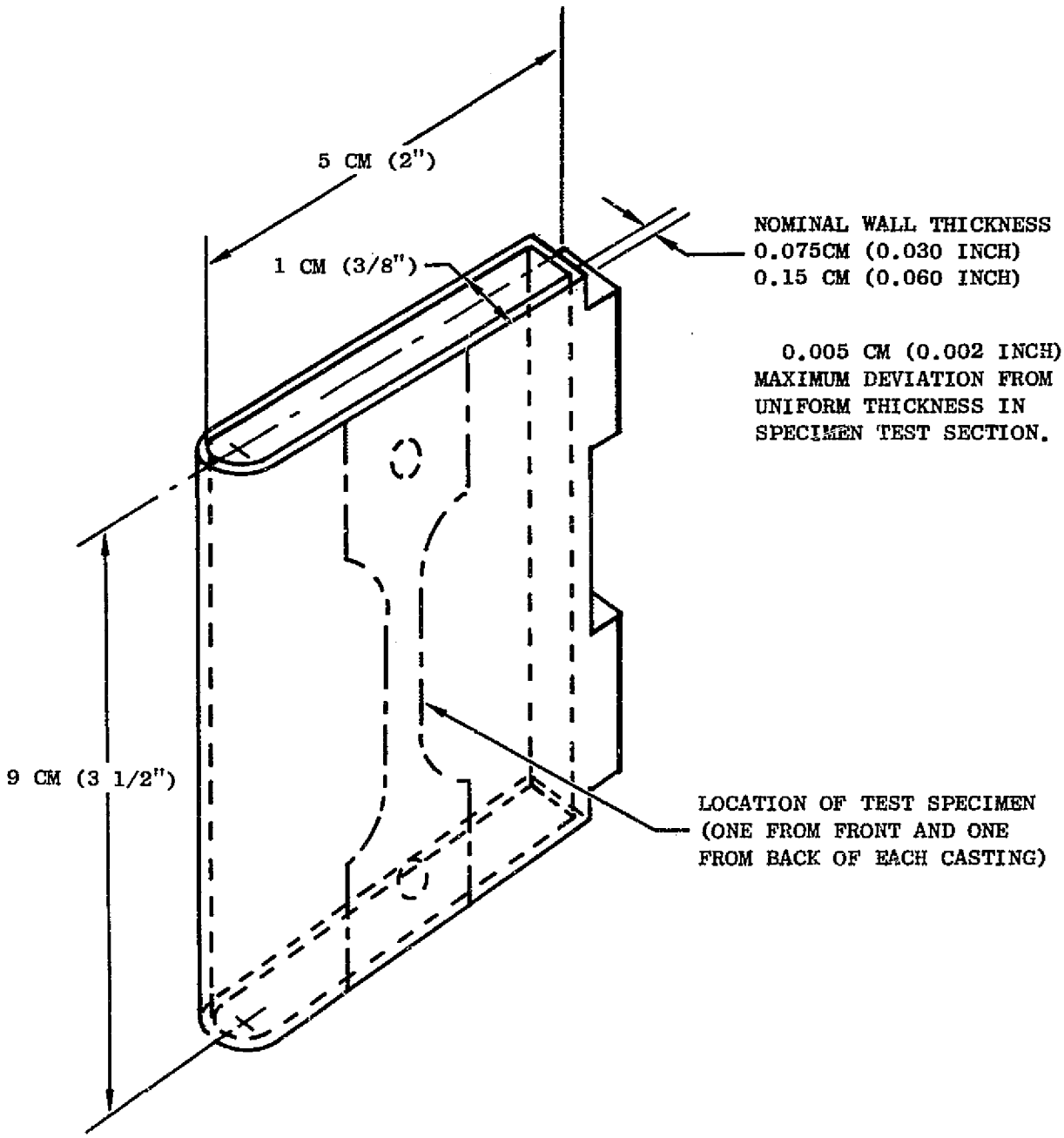


Figure 1 Thin Wall Cast S[illegible]eralloy Specimen

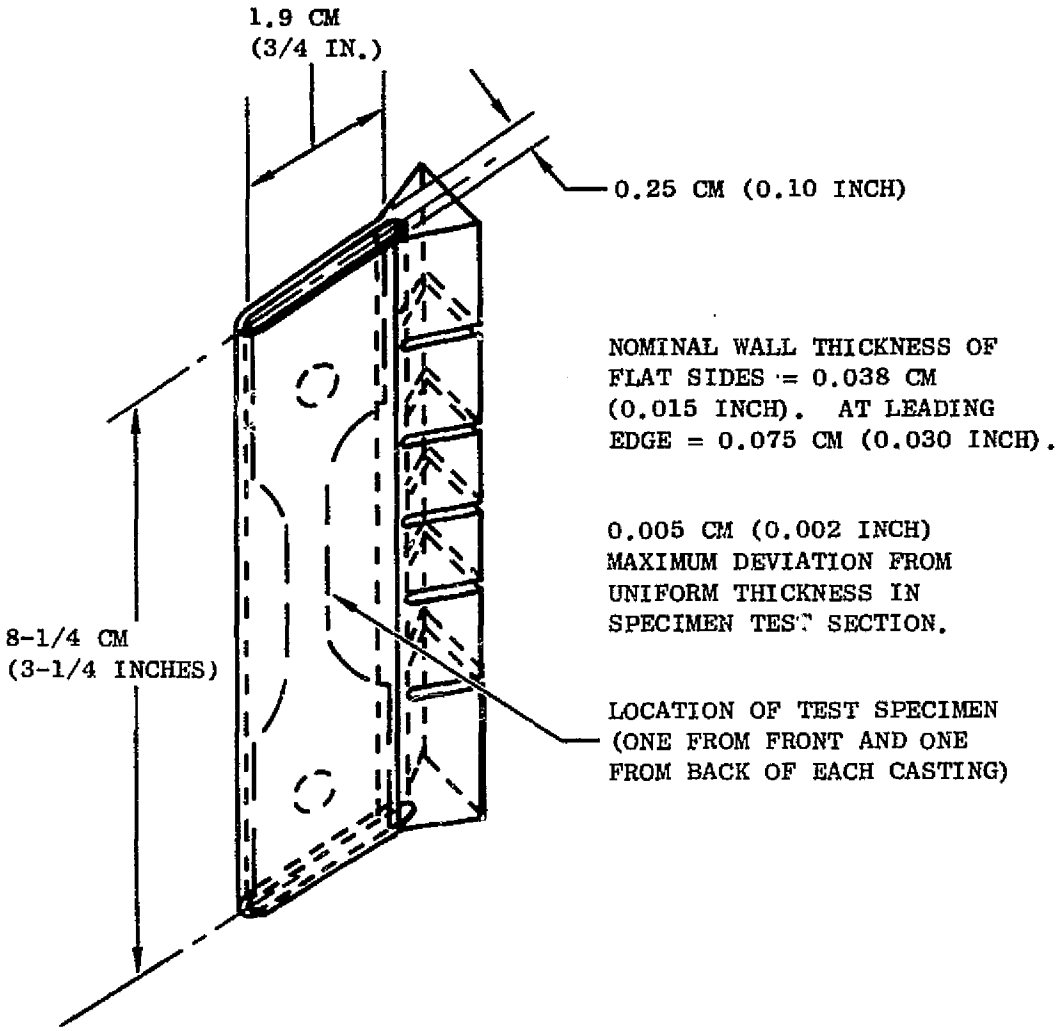
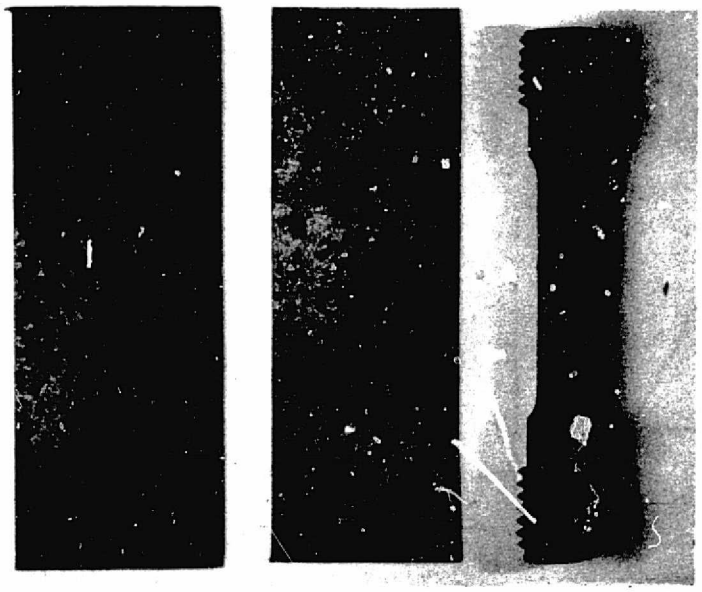
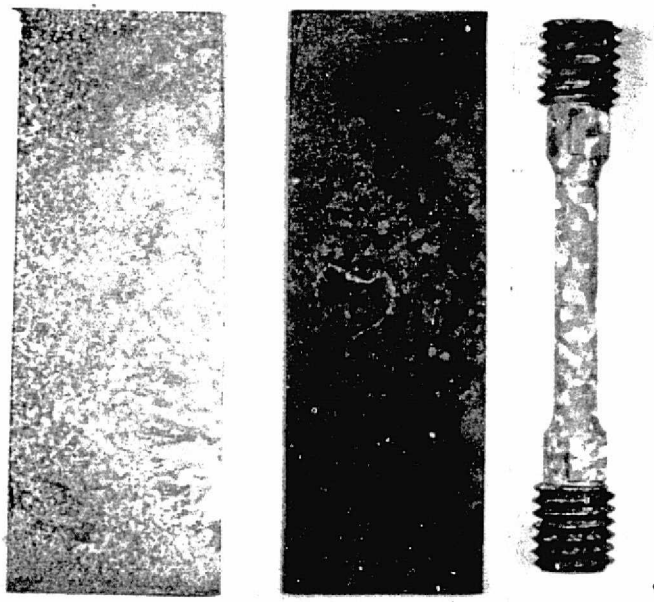


Figure 2 Thin Wall Cast Superalloy Specimen, 0.038CM Thickness



0.15cm thick 7535A2 | 0.075cm thick 7617D2 | 0.64cm dia. Std. Bar

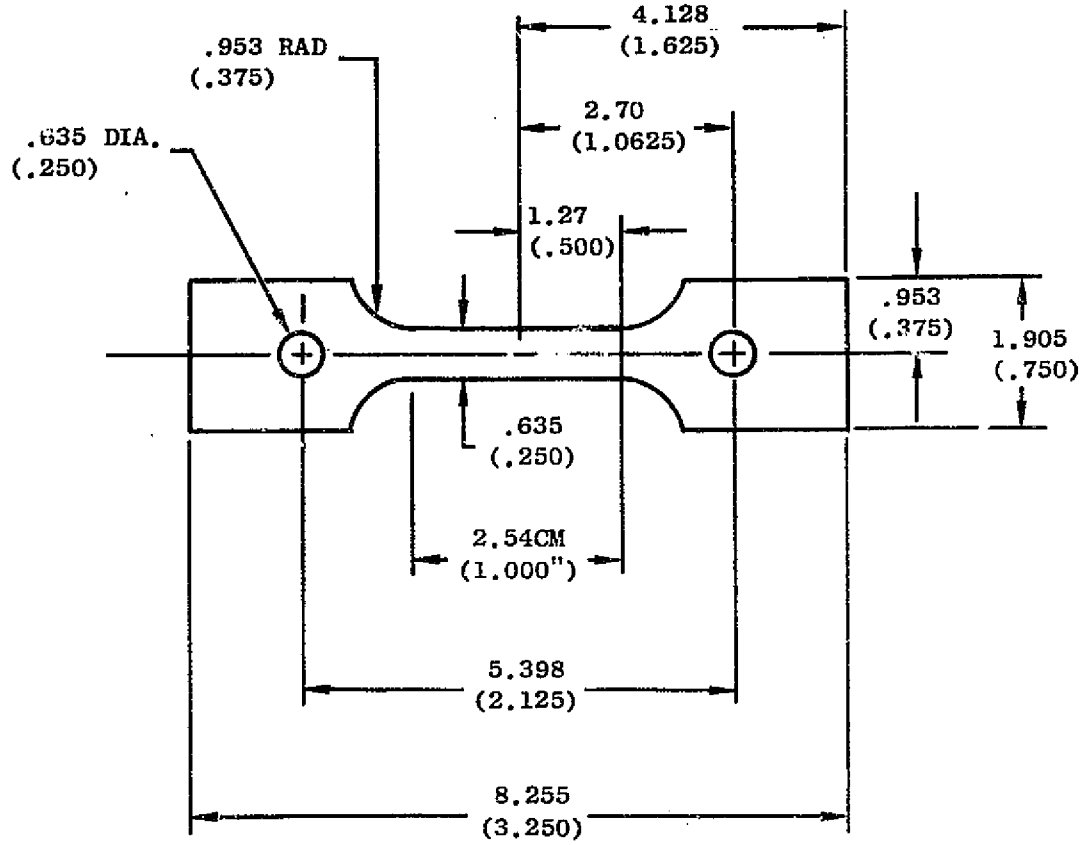
a. Rene 80 Specimens, magnification 0.95X



0.15cm thick B38240 | 0.075cm thick C38576 | 0.64cm dia. Std. Bar

b. Rene 120 Specimens, magnification 1.0X

Fig.3 Examples of Macrostructure of Cast Specimens

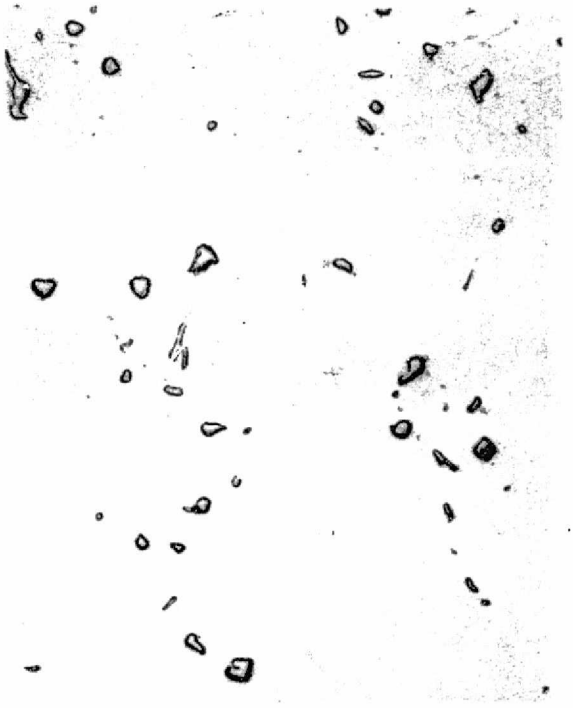


AS SMALL AS 7.62CM (3.00") FOR 0.038CM THICKNESS

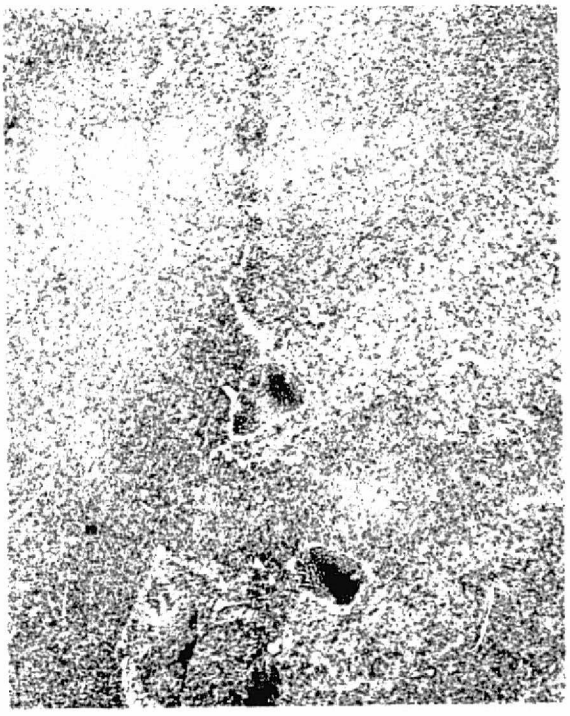
NOTES:
1. RADIUS & GAGE SECTION TO BLEND SMOOTHLY WITHOUT UNDERCUTS.
2. REMOVE ALL BURRS & SHARP EDGES WITH .0481CM (.015") MAXIMUM RADIUS.
3. GAGE SECTION TO BE CONCENTRIC TO CENTER LINE OF PIN HOLES WITHIN .0051CM (.002").
4. TOLERANCE OF GAGE SECTION WIDTH TO BE .0025CM (.001").

Figure 4 Mechanical Property Test Specimen

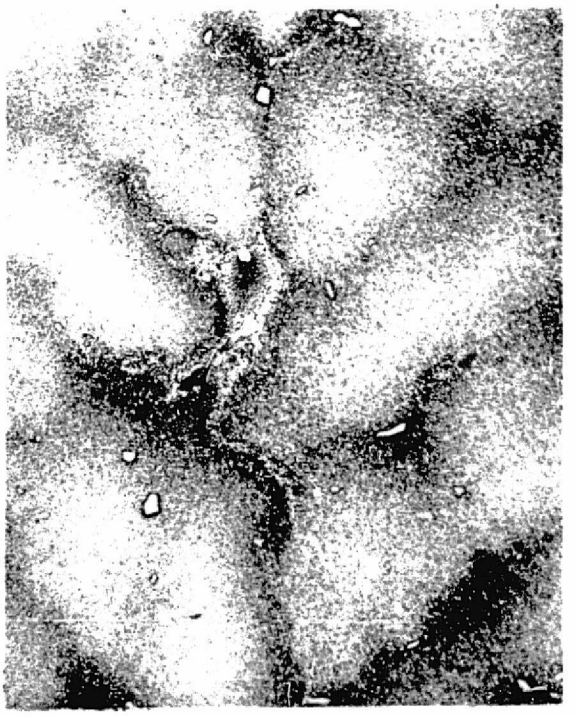
a. 0.075 cm Spec. 7617D2, unetched, 400X, normal MC



b. 0.15 cm Spec. 7535A2, unetched, 400X, coaser MC than (a).



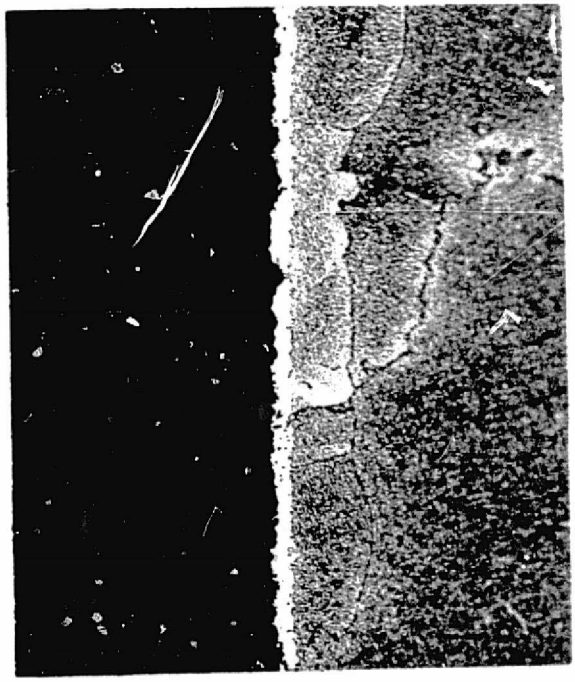
c. Same as (a), 92-5-3 etch, 400X, fine γ' and eutectic γ'



d. Same as (b), 92-5-3 etch, 400X, fine γ' and coarser γ' eutectic than (c)

Fig. 5 Microstructures of Rene 80 Specimens, As Cast

a. 0.15 cm Spec. 7534B4A, Heat B322 bare, carbide etch, grain boundary carbide particles

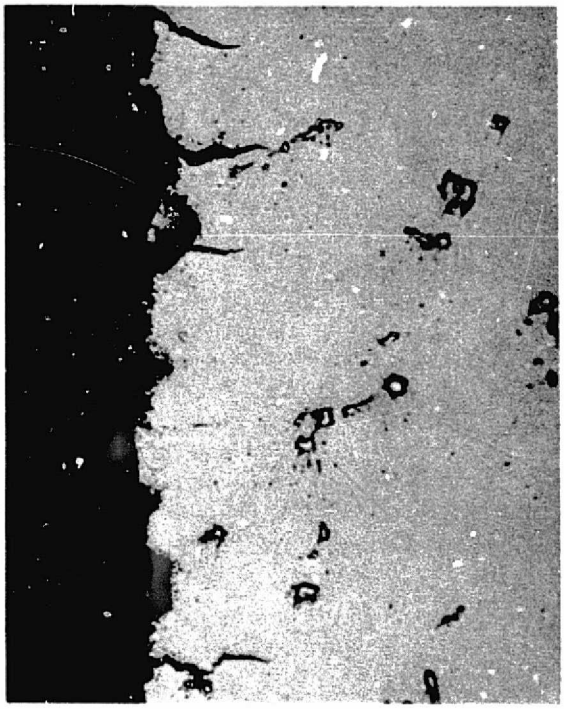


b. Same as (a), 92-5-3 etch, internal γ' and surface de-alloyed layer

c. 0.075 cm Spec. 7617A4B, Heat B322 Codep B-1 coated, carbide etch, absence of carbides directly below coating

d. Same as (c), 92-5-3 etch, normal internal structure

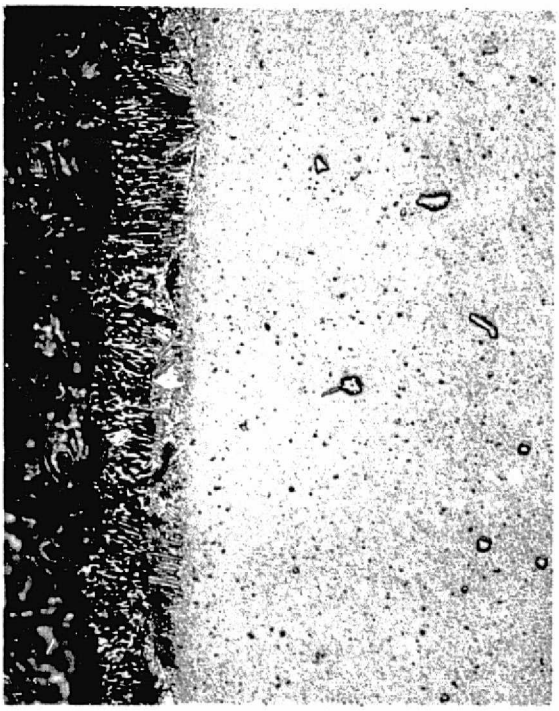
Fig. 6 Microstructures of Rene 80 Specimens, Full Heat Treatment, 400X



a. 0.038 cm Spec. 7183B, bare tested at 982C, unetched, 400X, surface cracks.

b. Same as (a), 92-5-3 etch, 200X, fracture appearance

c. 0.038 cm Spec. 7070B, coated, tested at R.T., unetched, 400X, fracture and coating cracks



d. Same as (c), 92-5-3 etch, 400X, coating diffusion zone structure

Fig. 7 Microstructures of Rene 80 Tensile Test Specimens

e. 0.15 cm Spec. 7534A4A, coated, tested at R.T., unetched, 400X, coating crack

f. Same as (e), 92-5-3 etch, coating cracks and structure

g. St'd. bar, Heat B353, coated, unetched, 100X, tested at R.T., coating cracks and fracture

h. St'd. bar, Heat B353, coated, unetched, 100X, tested at 871C, intact coating and fracture

Fig. 7 (Cont.) Microstructures of Rene 80 Tensile Test Specimens

a. St'd. bar, Heat B322, tested at 871C, 262 MN/m^2, 780 hours, unetched, 400X, surface attack

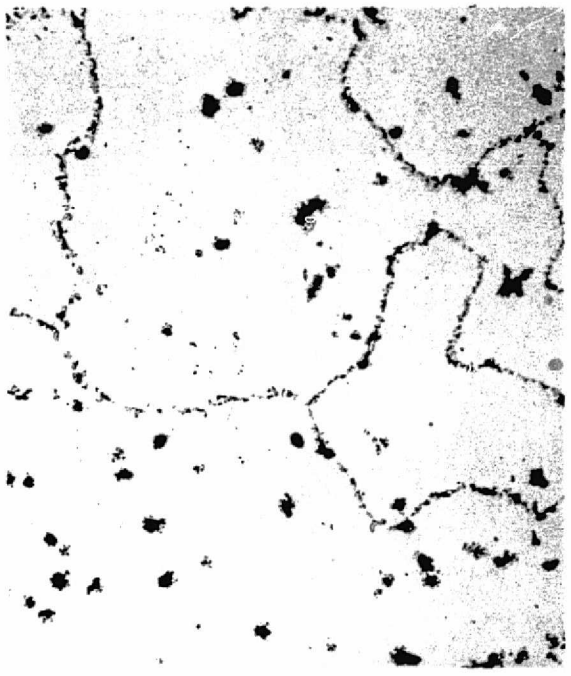
b. 0.15 cm Spec. 7535A1A, tested at 982C, 144 MN/m^2, 130.5 hrs, unetched, 400X, surface attack

c. 0.075 cm Spec. 7616D4A, tested at 982C, 117 MN/m^2, 93.0 hrs, 92-5-3 etch, 400X, surface attack

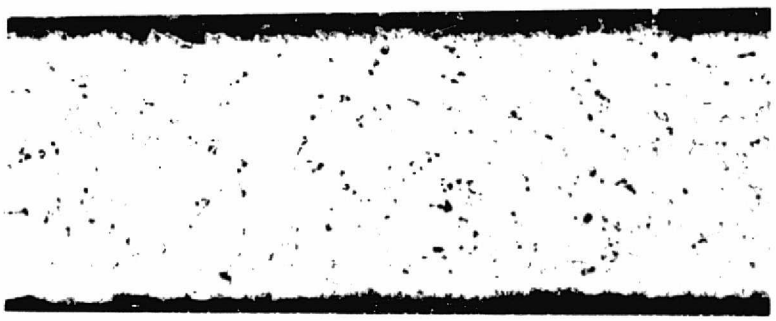
d. 0.075 cm Spec. 7616C1A, tested at 1093C, 34.5 MN/m^2, 70.7 hrs, 92-5-3 etch, 400X, surface attack

Fig. 8 Microstructures of Rene 80 Uncoated Stress Rupture Test Specimens

e. 0.038 cm Spec. 7193AB, tested at 1093C, 34.5 MN/m^2, 43.7 hrs. unetched, 120X, surface attack and fracture

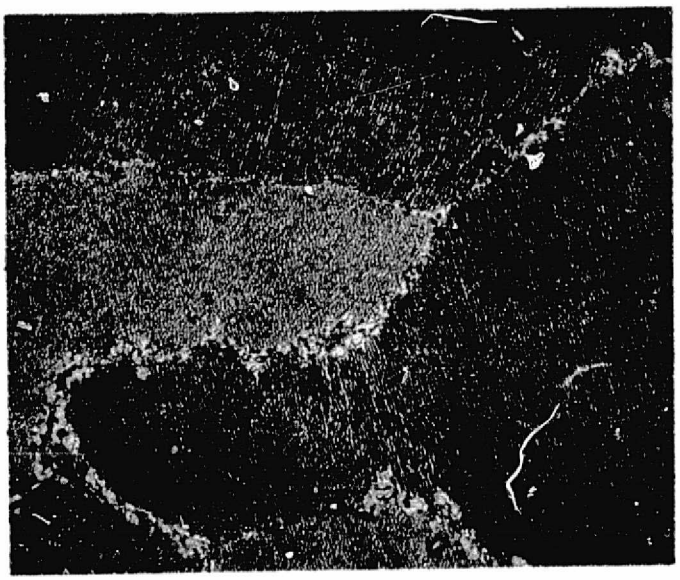


f. 0.15 cm Spec. 7534B4B, tested at 982C, 117 MN/m^2, 142.9 hrs, carbide etch, 400X, heavy grain boundaries $M_{23}C_6$

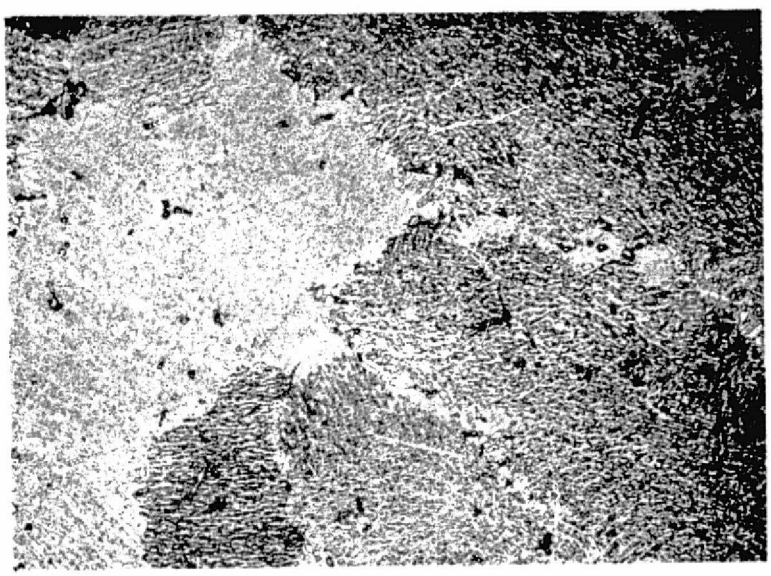


g. 0.038 cm Spec. 7185AA, tested at 982C, 117 MN/m^2, 24.2 hrs, carbide etch, 100X, surface attack and grain boundary precipitates

Fig. 8 (Cont.) Microstructures of Rene 80 Uncoated Stress Rupture Test Specimens



h. St'd. bar, Heat B322, tested at 982C, 144 MN/m², 147 hrs, 92-5-3 etch, 400X, grain boundary particles and γ'

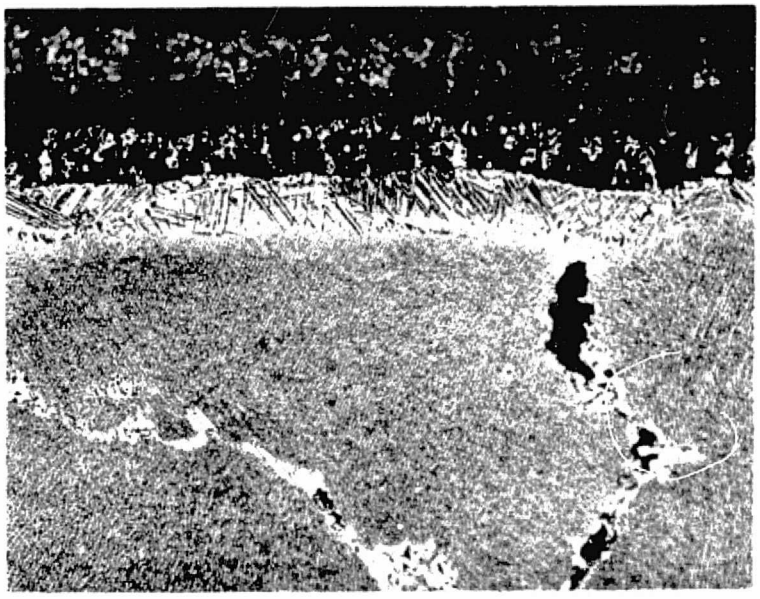


i. 0.075 cm Spec. 7617C1A, tested at 1093C, 34.5 MN/m², 70.7 hrs, 92-5-3 etch, 400X, coarse γ' and grain boundary particles

Fig. 8 (Cont.) Microstructures of Rene 80 Uncoated Stress Rupture Test Specimens

a. 0.075 cm Spec. 7616D2A, tested at 982C, 117 MN/m^2, 76.0 hrs, unetched, coating appearance

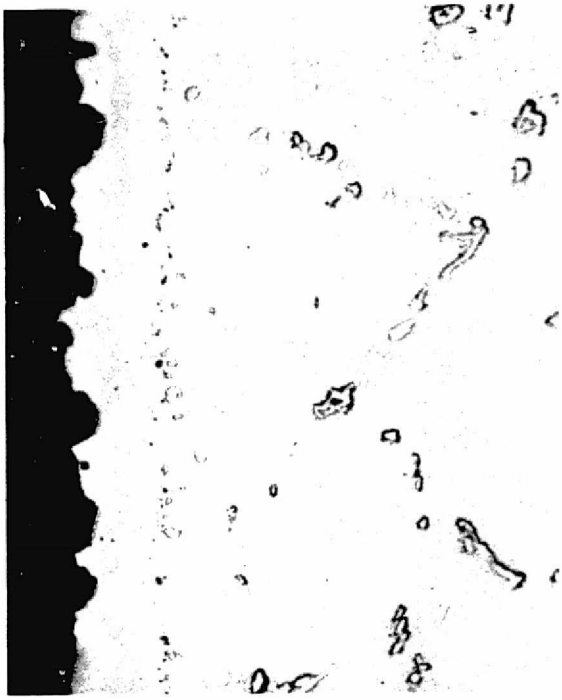
b. 0.15 cm Spec. 7534A1B, tested at 982C, 144 MN/m^2, 50.9 hrs, carbide etch, sub-coating structure



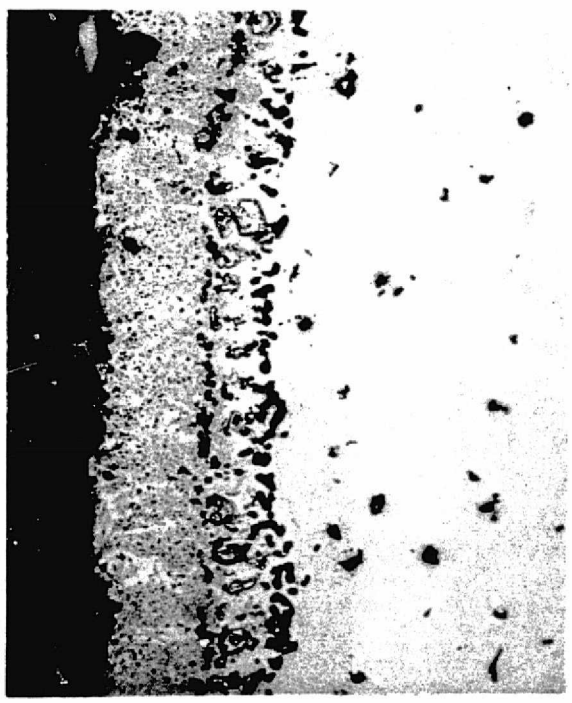
c. 0.15 cm Spec. 7537A2B, tested at 982C, 117 MN/m^2, 167.9 hrs, 92-5-3 etch, creep voids

Fig. 9 Microstructure of Rene 80 Codep B-1 Coated Stress Rupture Specimens, 400X

d. 0.075 cm Spec. 7621B4A, tested at 1093C, 34.5 MN/m^2, 46.1 hrs, unetched, coating agglomeration and transformation

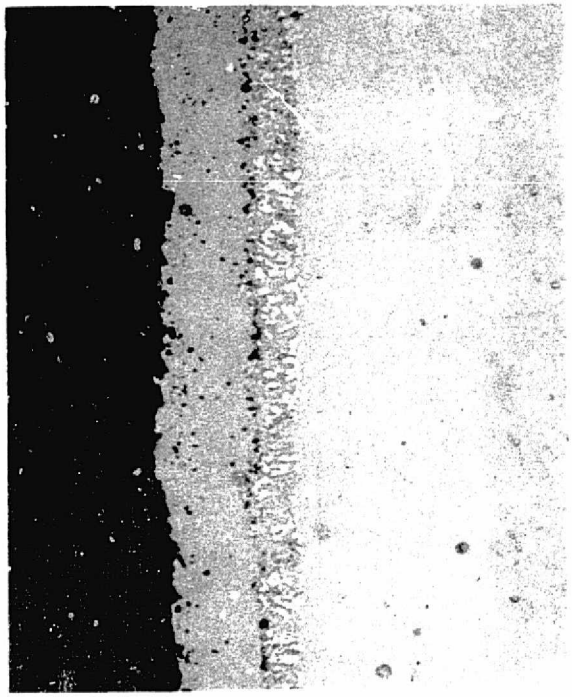


e. St'd. bar, Heat B322, tested at 1093C, 34.5 MN/m^2, 235.1 hrs, unetched, greater changes than (d)

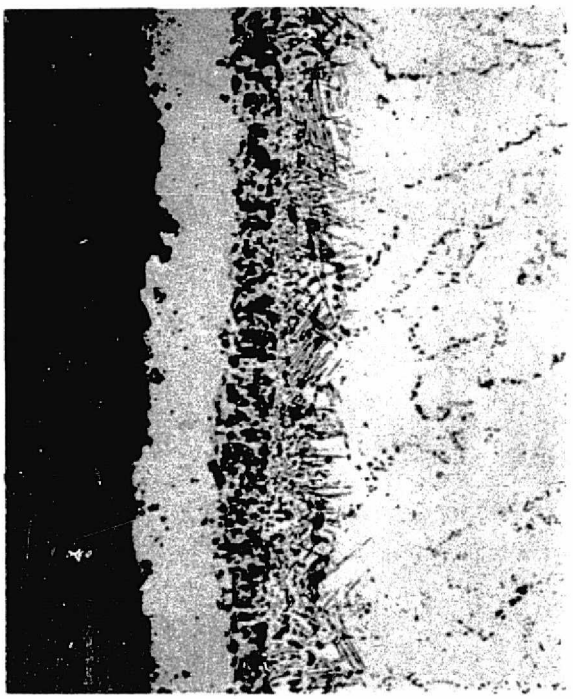


f. 0.15 cm Spec. 7538A2A, tested at 1093C, 34.5 MN/m^2, 110.4 hrs, carbide etch, coating and diffusion zone changes

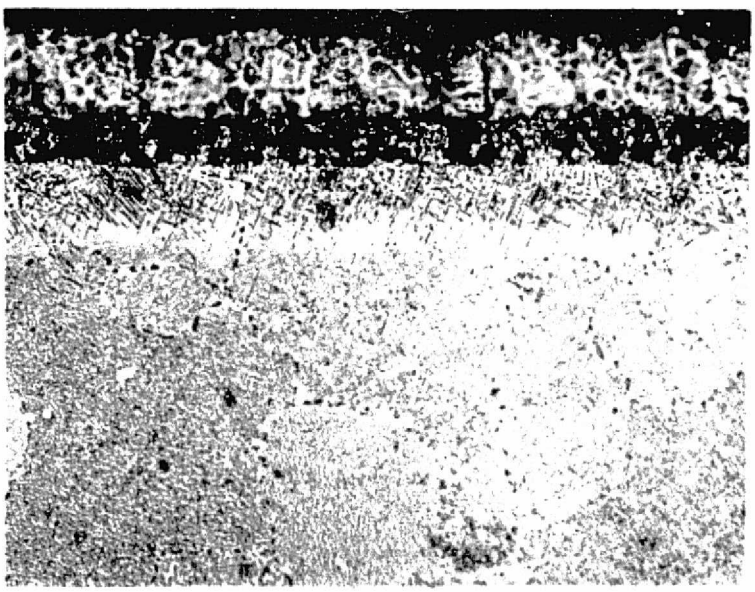
Fig. 9 (Cont.) Microstructure of Rene 80 Codep B-1 Coated Stress Rupture Specimens, 400X



a. 0.075 cm Spec. 7620C3A, unetched, coating appearance

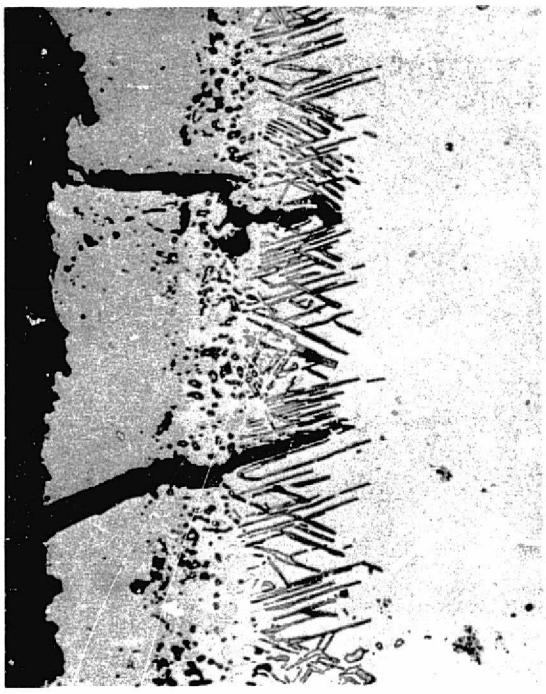


b. Same as (a), carbide etch, acicular particles below coating

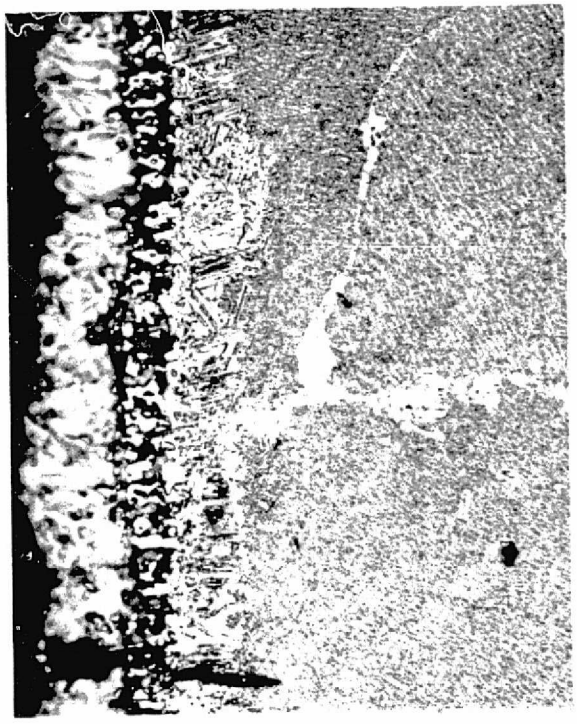


c. Same as (a), 92-5-3 etch, internal and sub-diffusion zone structure

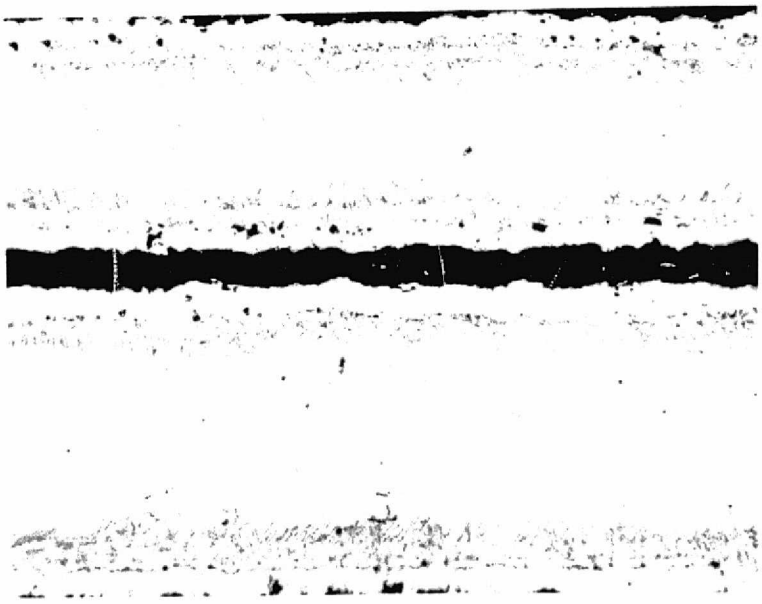
Fig. 10 Microstructures of Rene 80, Coated and Exposed 997 Hours at 899C, 400X



a. 0.038 cm Spec. 7189BB, tensile tested at R.T., carbide etch, 400X, coating cracks and acicular phase



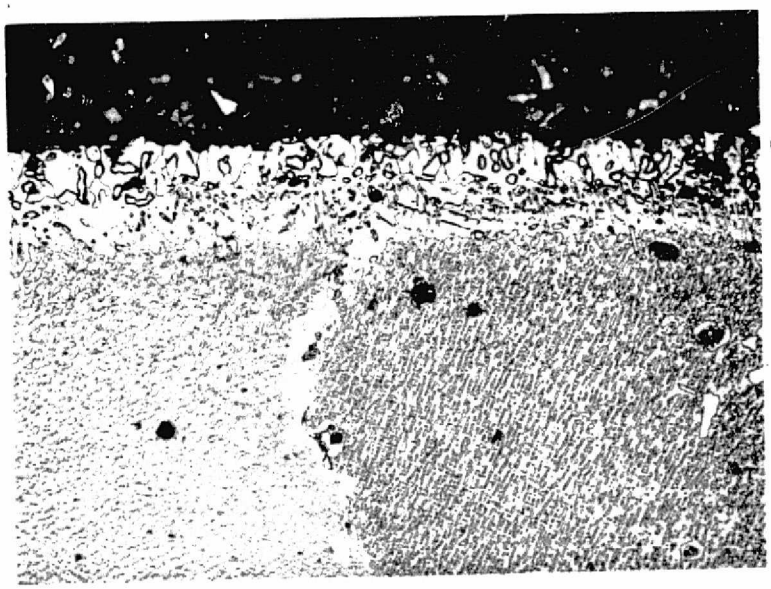
b. 0.15 cm Spec. 7539C1A tensile tested at R.T., 92-5-3 etch, 400X, sub-coating and coarse grain boundary phases



c. 0.038 cm Spec. # above, carbide etch, 95X, affected cross section, lack of MC

Fig. 11 Microstructures of Rene 80, Coated and Exposed ~1000 Hours at 982C

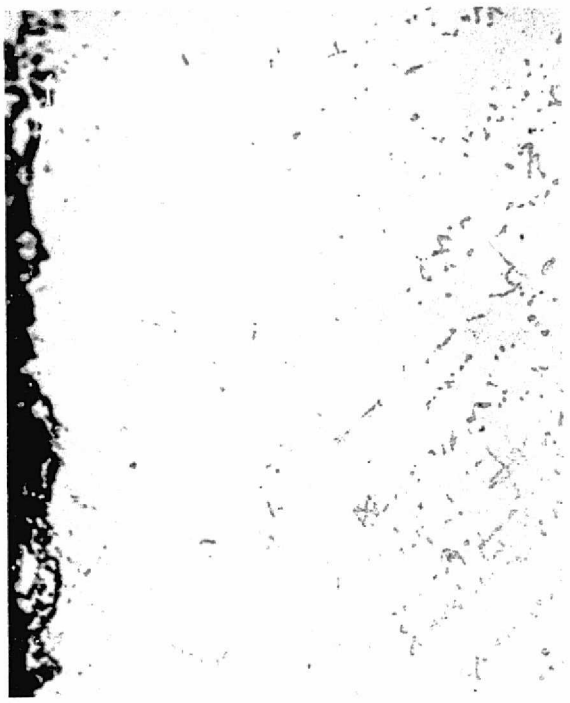
d. 0.038 cm Spec. 7197B, stress rupture tested at 871C, 262 MN/m^2, 15.9 hours, carbide etch, 200X, acicular phase, lack of MC, affected cross section



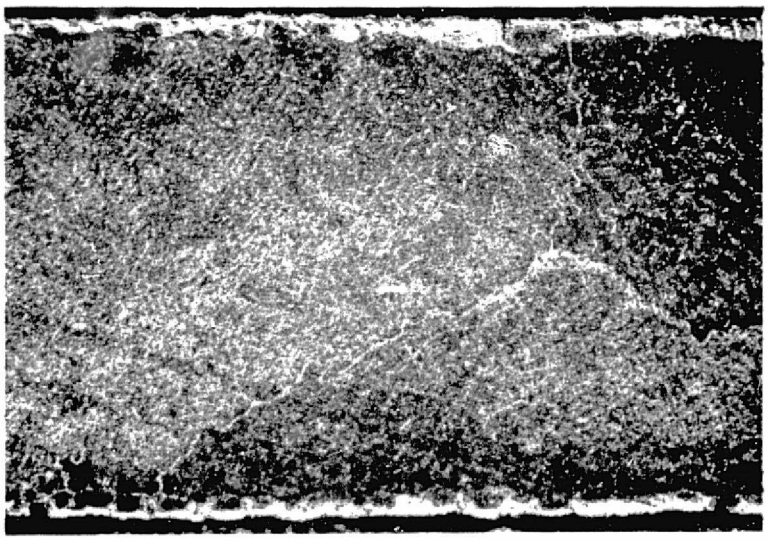
e. 0.15 cm Spec. 7534A3A stress rupture test at 1093C, 34.5 MN/m^2, 158.7 hrs, 92-5-3 etch, 400X, coarse γ' and grain boundaries

Fig. 11 (Cont.) Microstructures of Rene 80, Coated and Exposed ~1000 Hours at 982C

a. Spec. 8467A2A, tensile test at R.T., unetched, 100X, MC in dendritic pattern

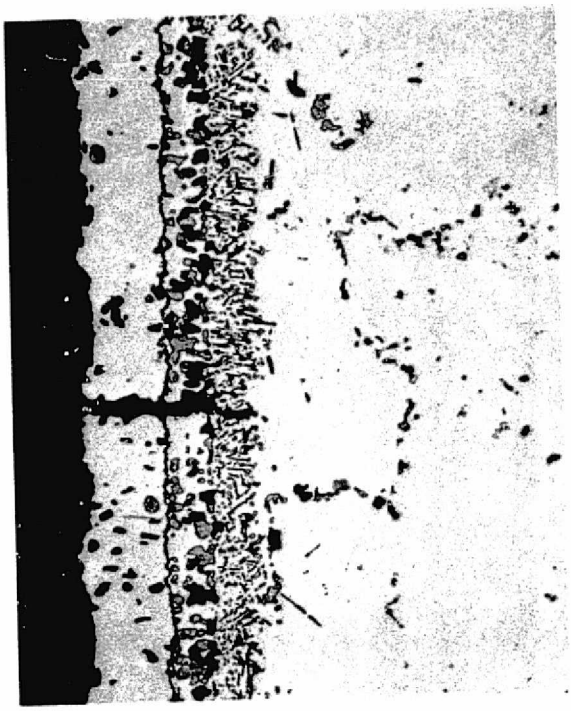


b. Same as (a), 320X, lack of MC near surface



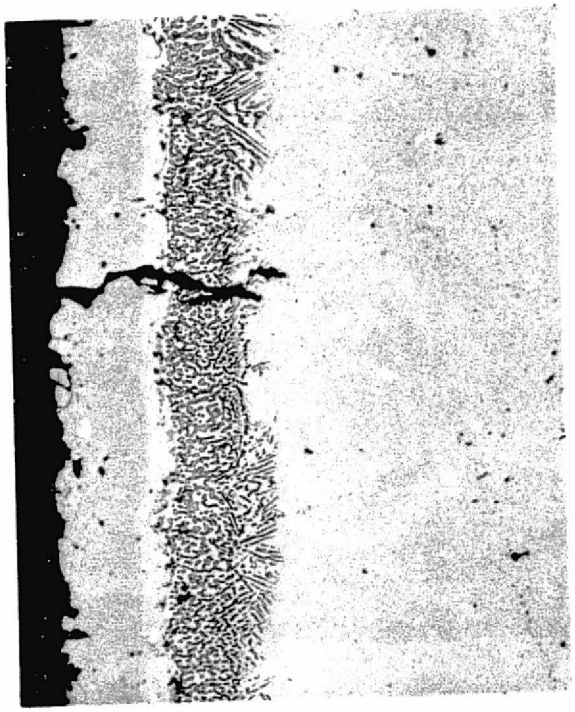
c. Spec. 8467B4B, rupture test at 871C, 262 MN/m^2, 169.6 hrs, 92-5-3 etch, surface cracks and coarse grain size, 90X

Fig. 12 Microstructures of Rene 80 Coarse Grain Specimens, 0.075 cm Thick (No [illegible] ating on Mold)

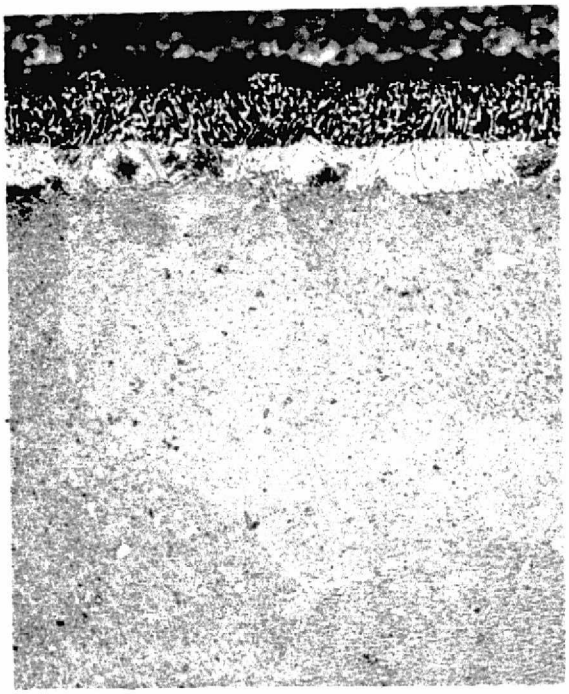


a. Spec. 4543D2B, exposed at 982C, tensile test at R.T., carbide etch, 400X, coating crack, diffusion zone changes, interior carbides

b. Spec. 47A, exposed at 982C, rupture test at 760C, 565 MN/m^2, 0.1 hrs, 92-5-3 etch, 400X, sub-coating and interior phases



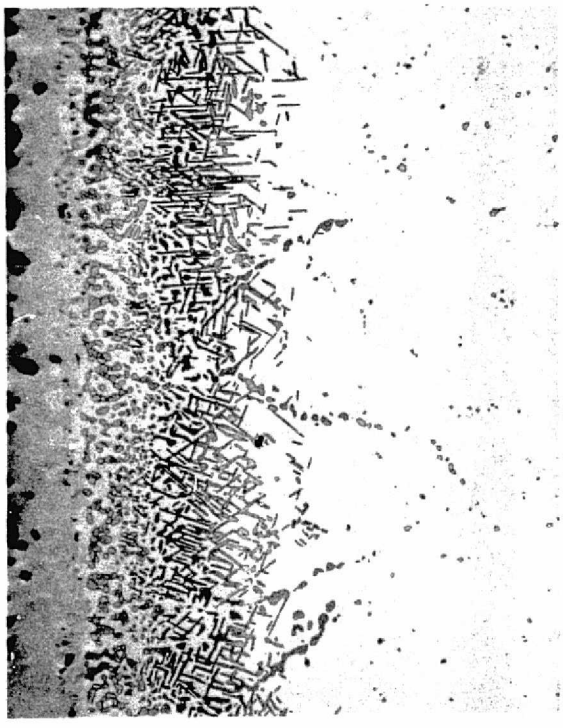
c. Spec. 15, exposed at 982C, re-surface machined and re-coated, rupture test at 760C, 565 MN/m^2, 0.1 hrs, carbide etch, 400X, coating crack



d. Same as (c), 92-5-3 etch, 400X, sub-coating and interior structure

Fig. 13 Microstructures of Rene 80 0.075 cm Coated Surface Machined Specimens

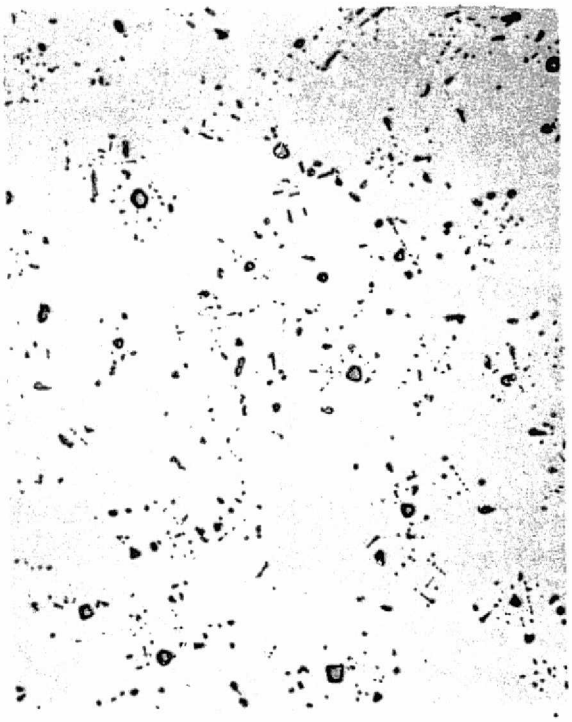
e. Spec. 109, exposed at 982C, re-surface machined, re-coated, re-exposed at 982C, rupture test at 871C, 262 MN/m^2, 3.9 hrs, unetched, 160X, fracture and loss of MC carbides throughout



f. Spec. 99, same condition as (e), rupture test at 982C, 117 MN/m^2, 2.2 hrs, carbide etch, 320X, coating changes and sub-coating phases

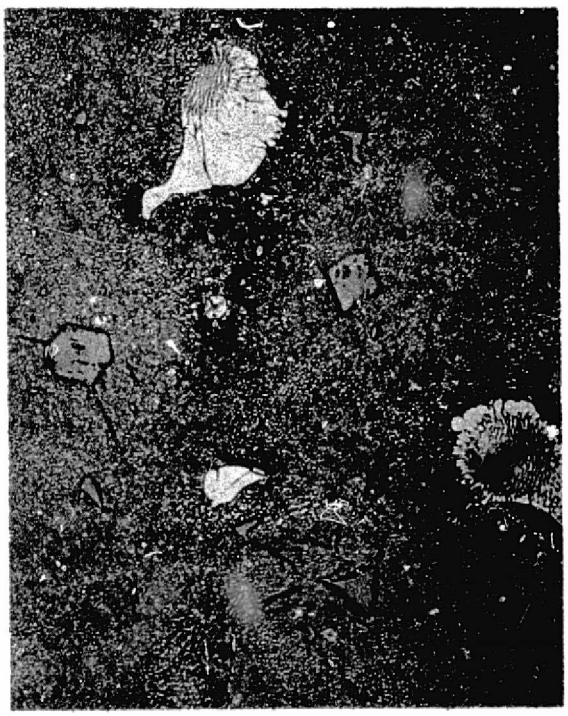
g. Spec. 46A, same condition as (e), rupture test at 760C, 565 MN/m^2, F.O.L., 92-5-3 etch, 400X, sub-coating phases, γ', coarse particles in grain boundaries

Fig. 13 (Cont.) Microstructures of Rene 80 0.075 cm Coated Surface Machined Specimens

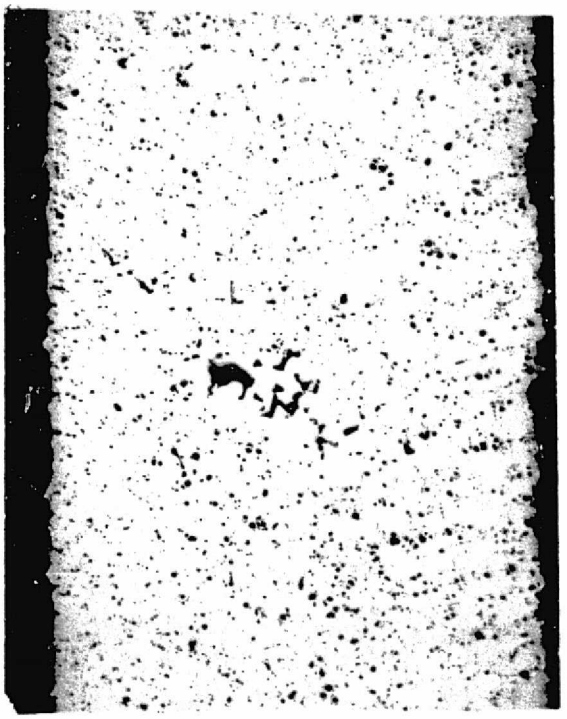


a. St'd. bar, Heat B325, unetched, 100X, MC distribution

b. Same as (a), 400X



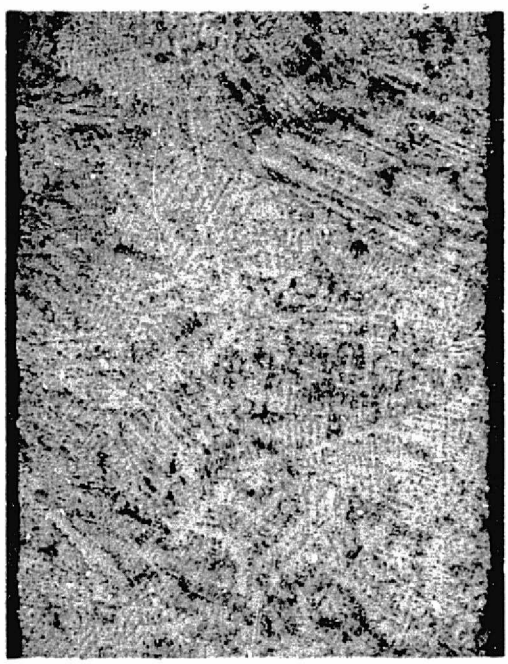
c. Same as (a), 92-5-3 etch, 400X, normal and eutectic γ'



d. 0.15 cm Spec. B38240, unetched, 50X, MC distribution and unacceptable porosity

Fig. 14 Microstructures of Rene 120 Specimens, As Cast

e. 0.075 cm Spec. C38578, unetched, 100X, MC distribution and worst accepted porosity

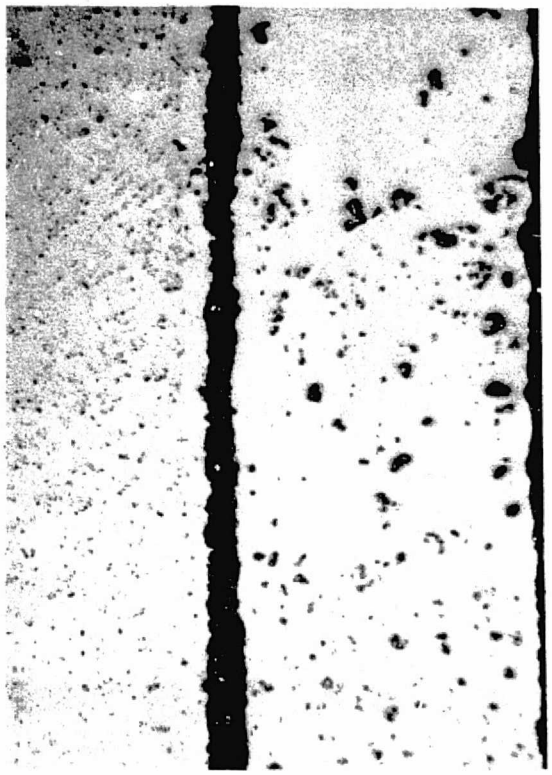


f. Same as (e), different area, 92-5-3 etch, 100X, grain size and dendritic appearance

g. Same as (e), unetched, 400X, eutectic MC appearance

h. Same as (f), 92-5-3 etch, 400X, normal and small eutectic γ' nodules

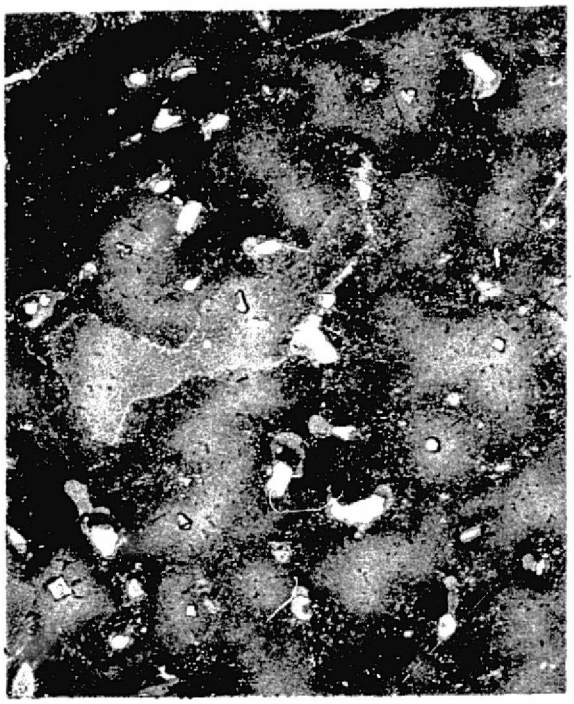
Fig. 14 (Cont.) Microstructures of Rene 120 Specimens, As Cast



i. 0.038 cm Trial casting, unetched, 100X, coarse carbides near gate, fine carbide distribution at test specimen area

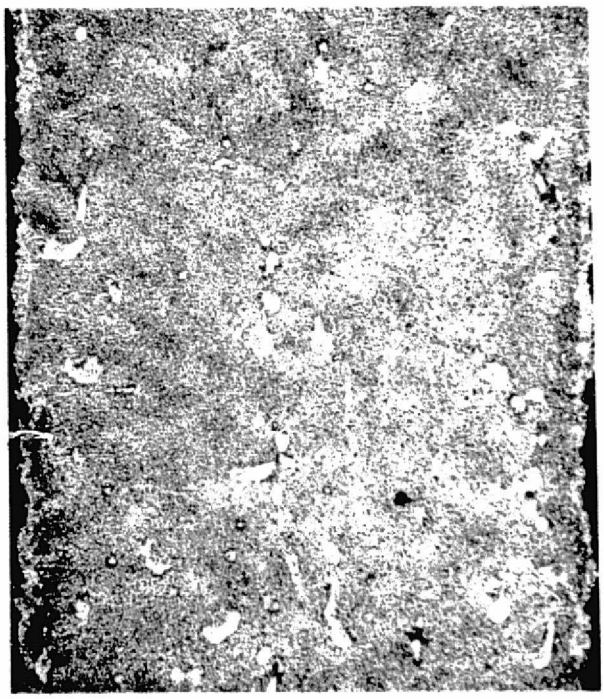
Fig. 14 (Cont.) Microstructures of Rene 120 Specimens, As Cast

a. St'd. bar, Heat B325, tested at R.T., carbide etch, 400X, fine grain boundary particles, normal MC



b. Same as (a), 92-5-3 etch, 100X, fine and eutectic γ' distribution

c. Same as (b), 400X, affected region around eutectic γ' nodules.

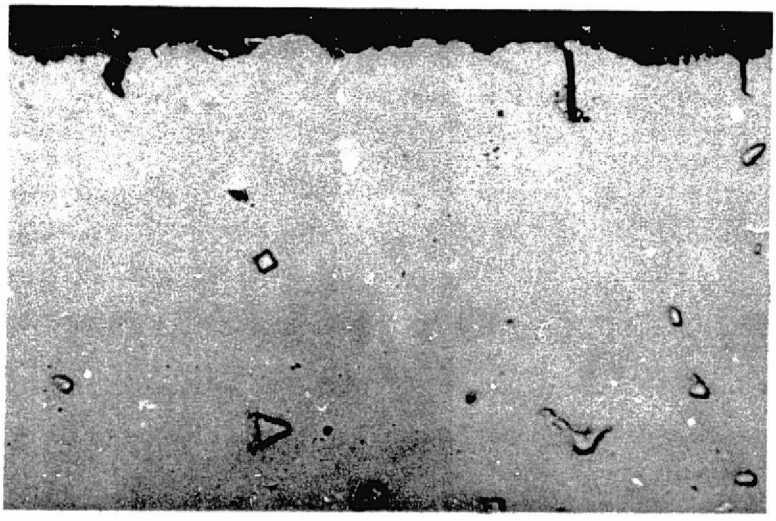


d. 0.038 cm Spec. 4A, tested at R.T., 92-5-3 etch, 180X, grain size and γ' distribution

Fig. 15 Microstructures of Rene 120, Full Heat Treatment, Uncoated, Tensile Tested

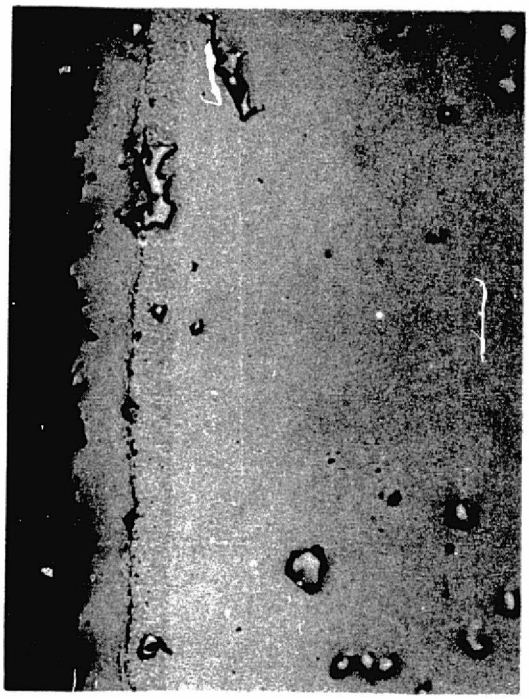
e. St'd. bar, Heat B415, tested at R.T., unetched, 100X, fracture appearance

f. Same as (e), 92-5-3 etch, 400X, fracture appearance



g. 0.15 cm Spec. 7660A1A, tested at 871C, unetched, 400X, surface cracks

Fig. 15 (Cont.) Microstructures of Rene 120 Heat Treated, Uncoated, Tensile Tested



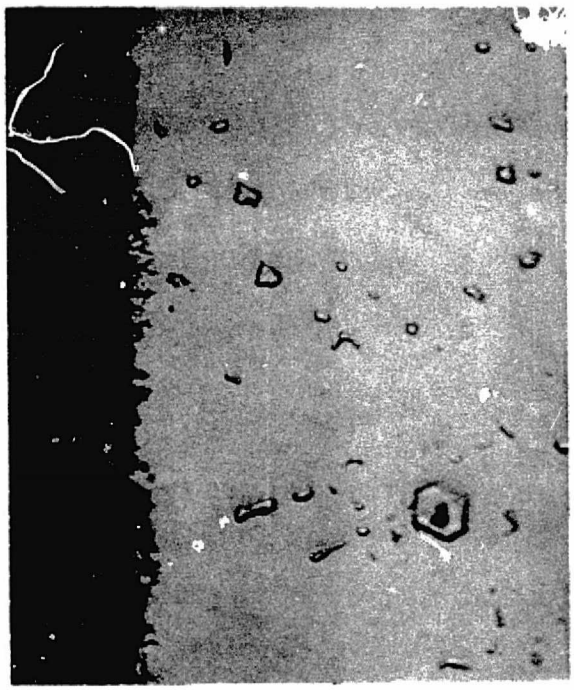
a. St'd bar, Heat B415, tested at R.T., unetched, 400X, normal coating with MC in diffusion zone

b. 0.075 cm Spec. C28577B, tested at R.T., carbide etch, 400X, diffusion zone and internal carbides

c. Same as (b), 92-5-3 etch, 400X, normal structure and eutectic γ' below coating

d. 0.15 cm coarse columnar grain Spec. C36401B, tested at 871C, 92-5-3 etch, 50X, grain size and γ' distribution

Fig. 16 Microstructures of Rene 120, Coated, Tensile Tested



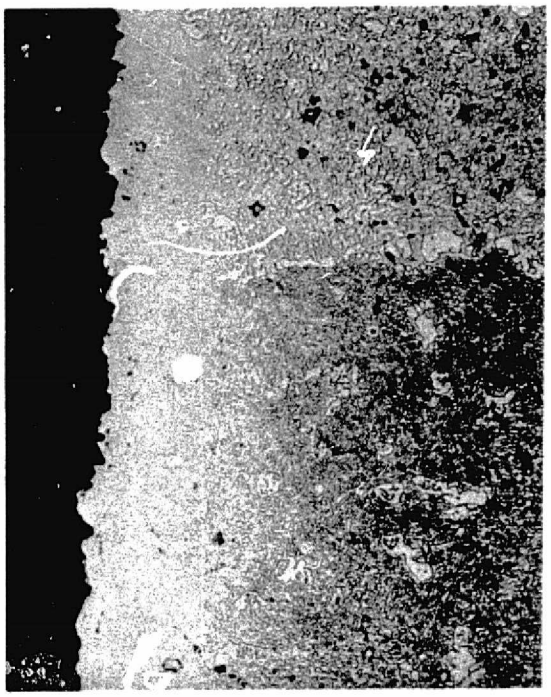
a. St'd. bar, Heat B325, tested at 871C, 379 MN/m^2, 182.4 hrs, unetched, 400X, surface attack

b. St'd. bar, Heat B325, tested at 982C, 172 MN/m^2, 102.7 hrs, unetched, 400X, surface attack

c. Same as (b), 92-5-3 etch, 400X, de-alloyed layer

Fig. 17 Microstructures of Rene 120, Uncoated, Stress Rupture Tested, 400X

d. 0.075 cm Spec. A22771B, tested at 1093C, 53 MN/m^2, 40.2 hrs, unetched, 400X, carbide free zone and surface attack

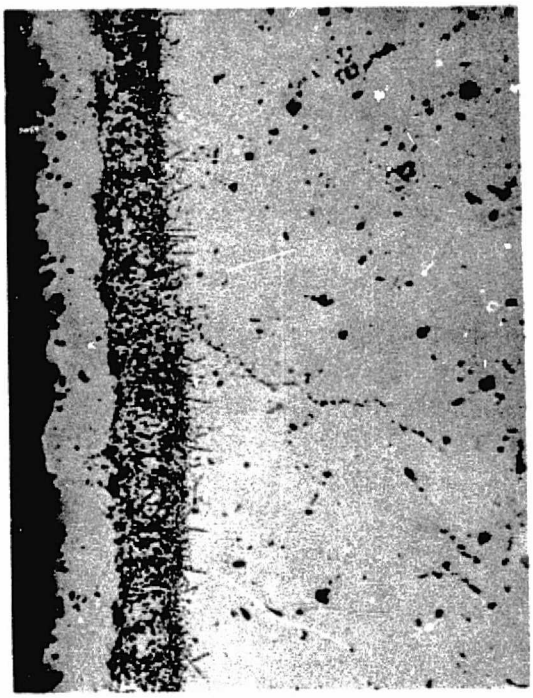


e. Same as (d), 92-5-3 etch, 400X, de-alloyed zone, coarsened γ' internally

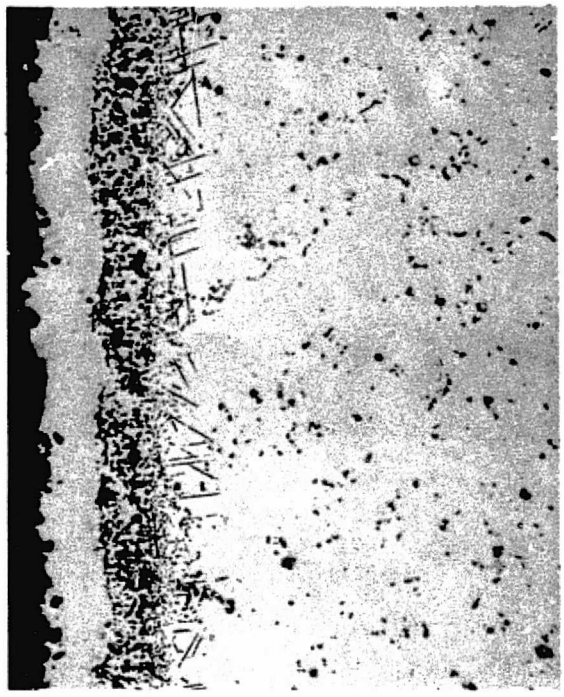
f. 0.15 cm Spec. C38240B, tested at 871C, 379 MN/m^2, 56.2 hrs, carbide etch, 400X, grain boundary particles

g. St'd. bar, Heat B325, tested at 1093C, 55 MN/m^2, 181.3 hrs, 92-5-3 etch, 400X, coarse internal γ', eutectic γ' nodule

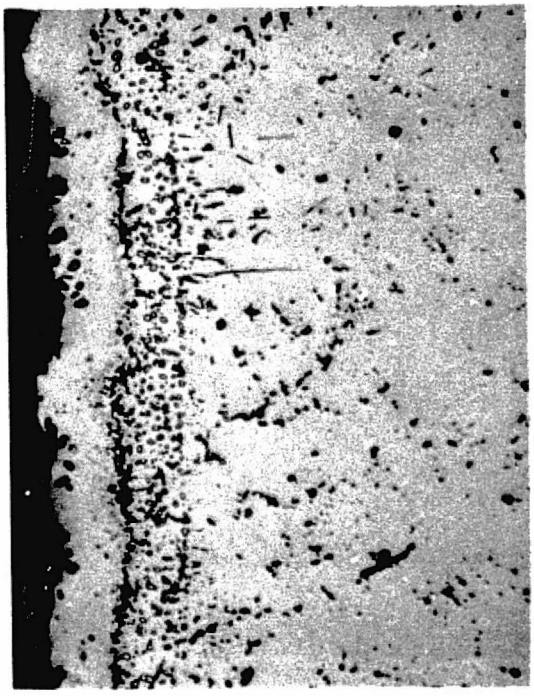
Fig. 17 (Cont.) Microstructures of Rene 120, Uncoated, Stress Rupture Tested, 400X



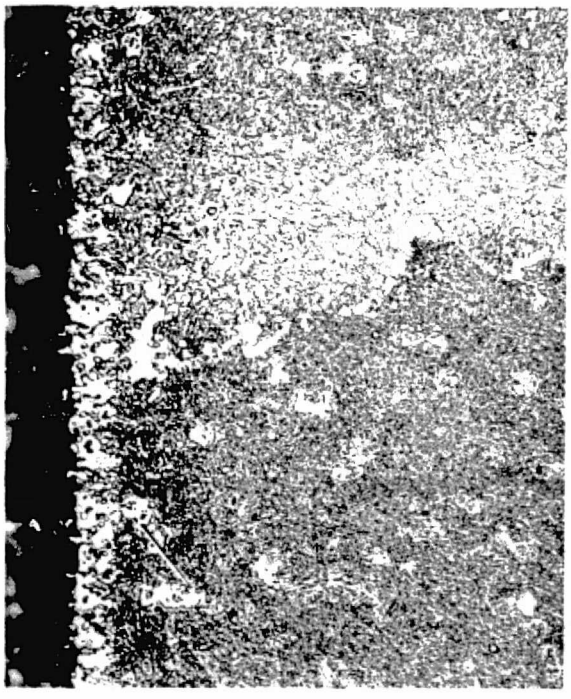
a. 0.075 cm Spec. D32771A, tested at 871C, 310 MN/m², 85.3 hrs, carbide etch, diffusion zone structure



b. 0.075 cm Spec. D32773B, tested at 982C, 145 MN/m², 59.7 hrs, carbide etch, change in diffusion zone and below

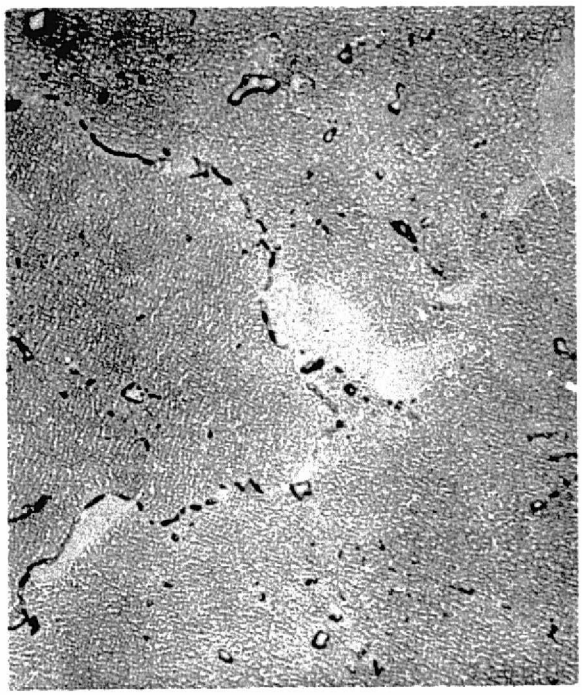


c. 0.075 cm Spec. D32772A, tested at 1093C, 55 MN/m², 91.4 hrs, carbide etch, agglomeration in diffusion zone

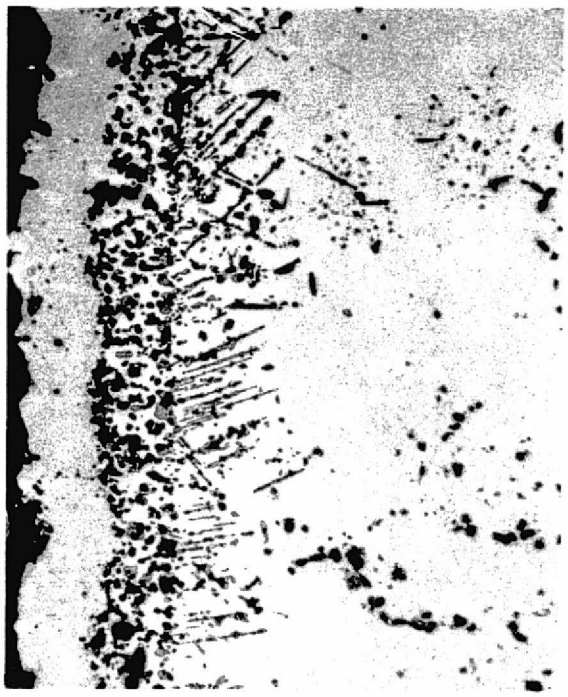


d. Same as (c), 92-5-3 etch, coarsened γ' and grain boundary phases below coating

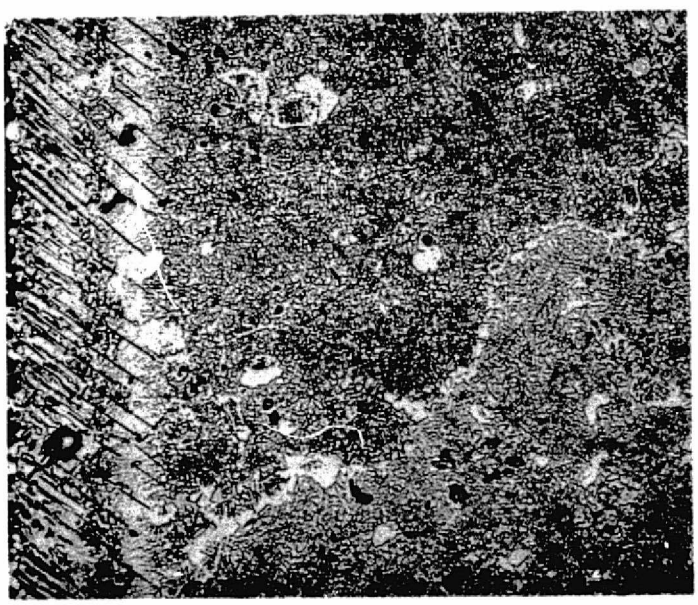
Fig. 18 Microstructures of Rene 80, Coated, Stress Rupture Tested, 400X



a. 0.15 cm Spec. C18241A, tensile test at R.T., 92-5-3 etch, coarser grain boundary particles and γ'

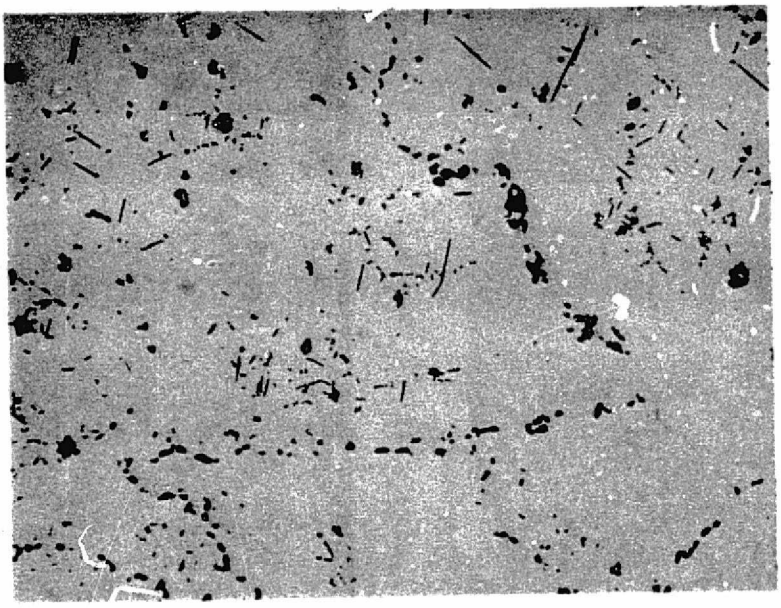


b. 0.075 cm Spec. C18581A, tensile test at R.T., carbide etch, coating changes and acicular particles below

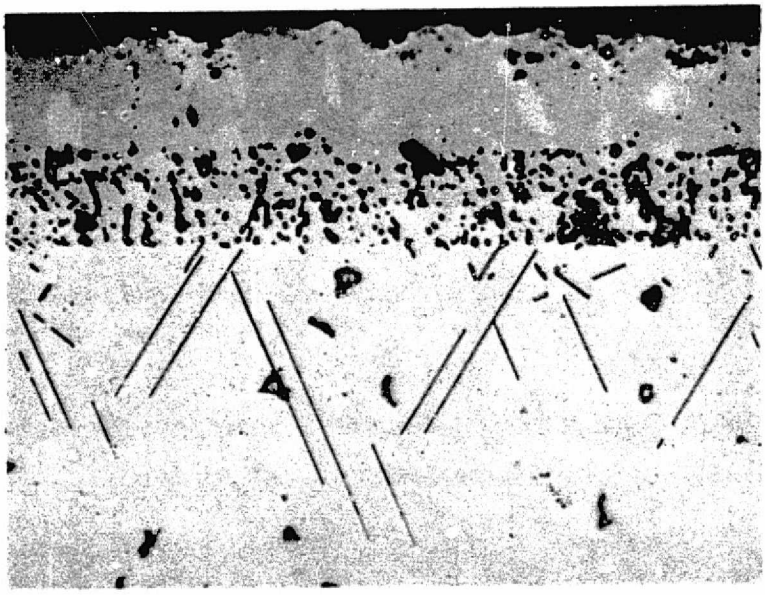


c. 0.075 cm Spec. B129354B, tensile test at R.T., 92-5-3 etch, phases below coating and coarser grain boundaries and γ'

Fig. 19 Microstructures of Rene 120, Coated, Exposed ~1000 Hours at 982C, Tested, 400X

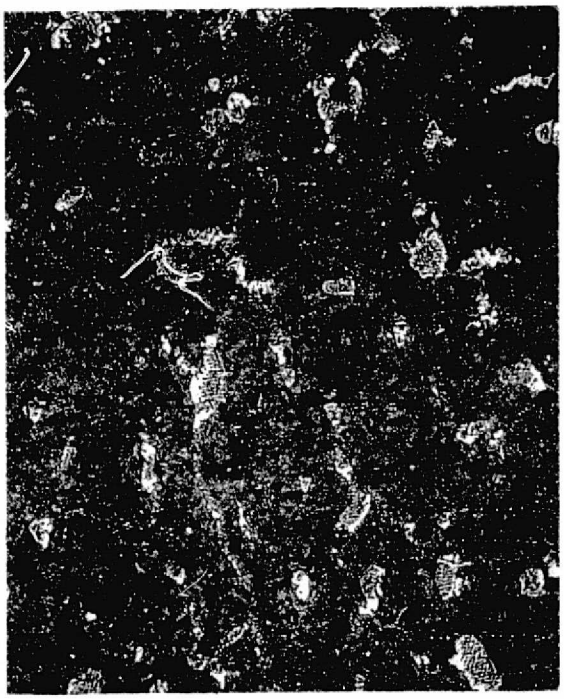


d. 0.075 cm Spec. B37658B, tensile test at 871C, carbide etch, coarse grain boundary particles, some acicular particles

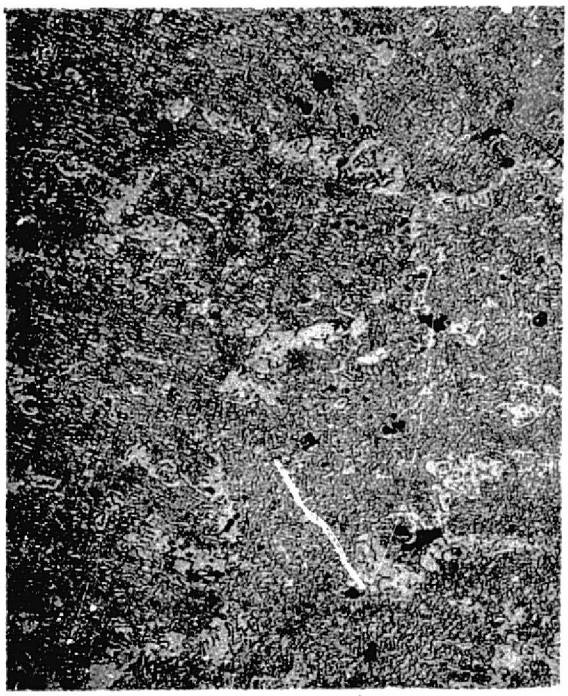


e. 0.15 cm coarse columnar grain Spec. B26401A, rupture test at 1093C, 55 MN/m^2, 127.2 hrs, carbide etch, coating transformation, few large needles below diffusion zone

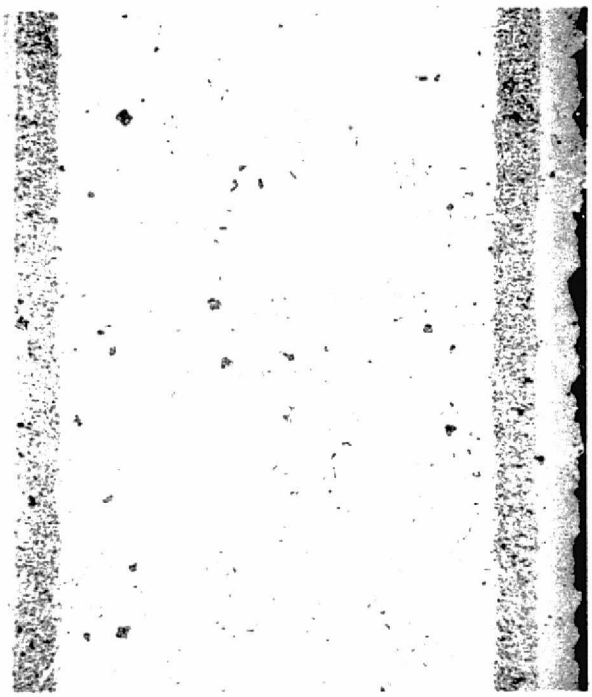
Fig. 19 (Cont.) Microstructures of Rene 120, Coated, Exposed 1000 Hours at 982C, Tested, 400X



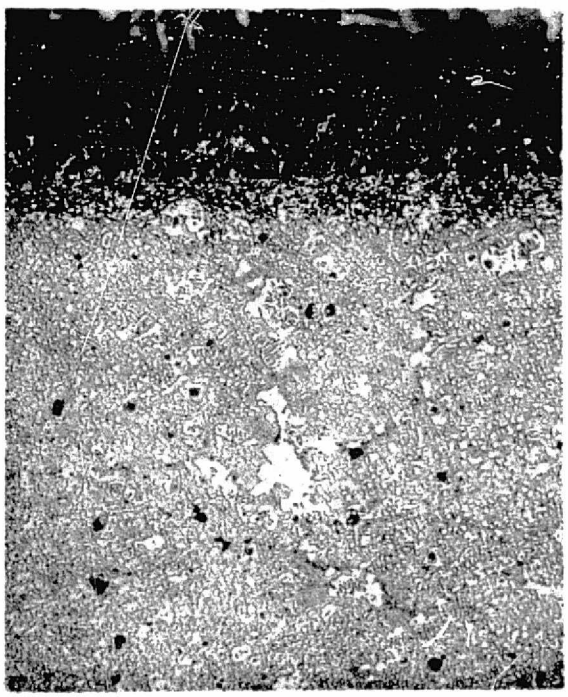
a. Spec. B32772, bare, tensile test at R.T., 92-5-3 etch, 400X, normal internal structure



b. Spec. D32772B, coated, exposed at 982C, re-surface machined, rupture test at 760C, 145 MN/m^2, 29.2 hrs, 92-5-3 etch, coarser γ' and altered eutectic γ' 400X

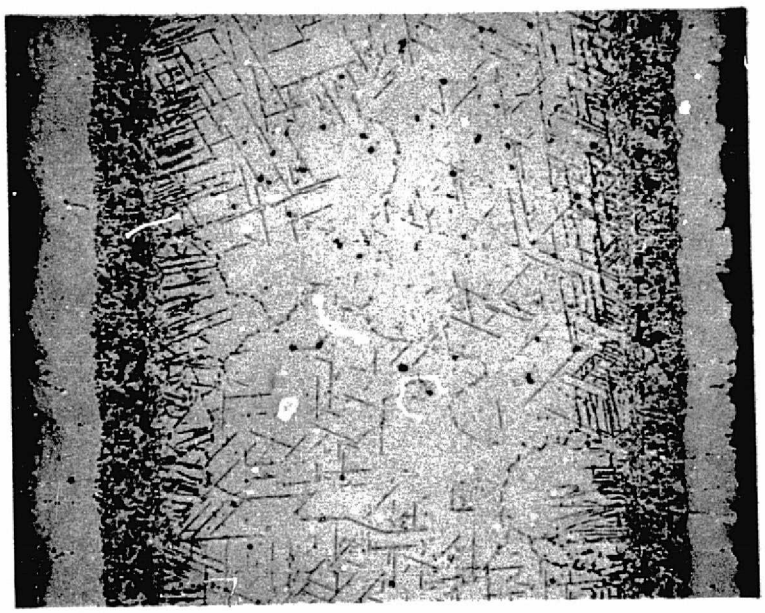


c. Spec. A16252A, coated, exposed, re-machined, re-coated, tensile test at 871C, carbide etch, 160X, little MC, normal coating



d. Spec. A32774, same condition as (c), tensile test at R.T., 92-5-3 etch, 400X, coarser internal γ', normal coating

Fig. 20 Microstructures of Rene 120 0.075 cm Surface Machined Specimens, Tested



e. Spec. B42780, coated, exposed, re-machined, re-coated, re-exposed at 982C, rupture test at 760C, 634 MN/m^2, F.O.L., carbide etch, 200X, coating deterioration, much acicular phase throughout, few MC

f. Same as (e), 92-5-3 etch, 400X, coarse γ' and acicular phase below coating, altered eutectic γ'

Fig. 20 (Cont.) Microstructures of Rene 120 0 075 cm Surface Machined Specimens, Tested

a. Spec. C44337, uncoated, unetched, 400X, sharp transgranular failure and cracks

b. Same as (a), 92-5-3 etch, 320X, crack goes through eutectic γ', changes direction at grain boundary

c. Spec. D38581A, coated, unetched, 200X, crack as in (a) plus second major failure

d. Spec. A48579B, coated, exposed at 982C, unetched, 200X, no sharp transgranular cracks

Fig. 21 Microstructures of Rene 120, High Cycle Fatigue Tested at R.T., 0.075 cm Specimens

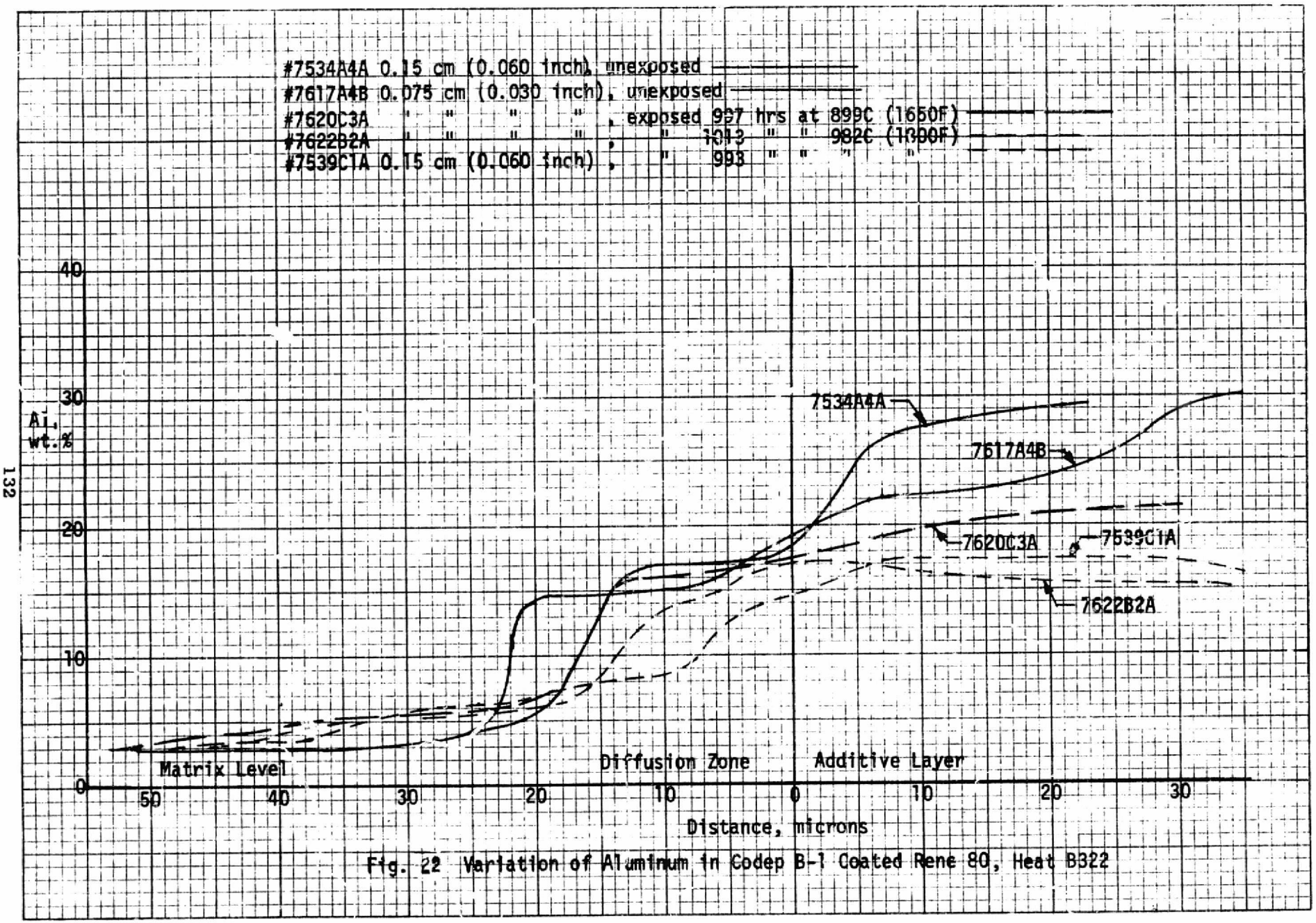


Fig. 22 Variation of Aluminum in Codep B-1 Coated Rene 80, Heat B322

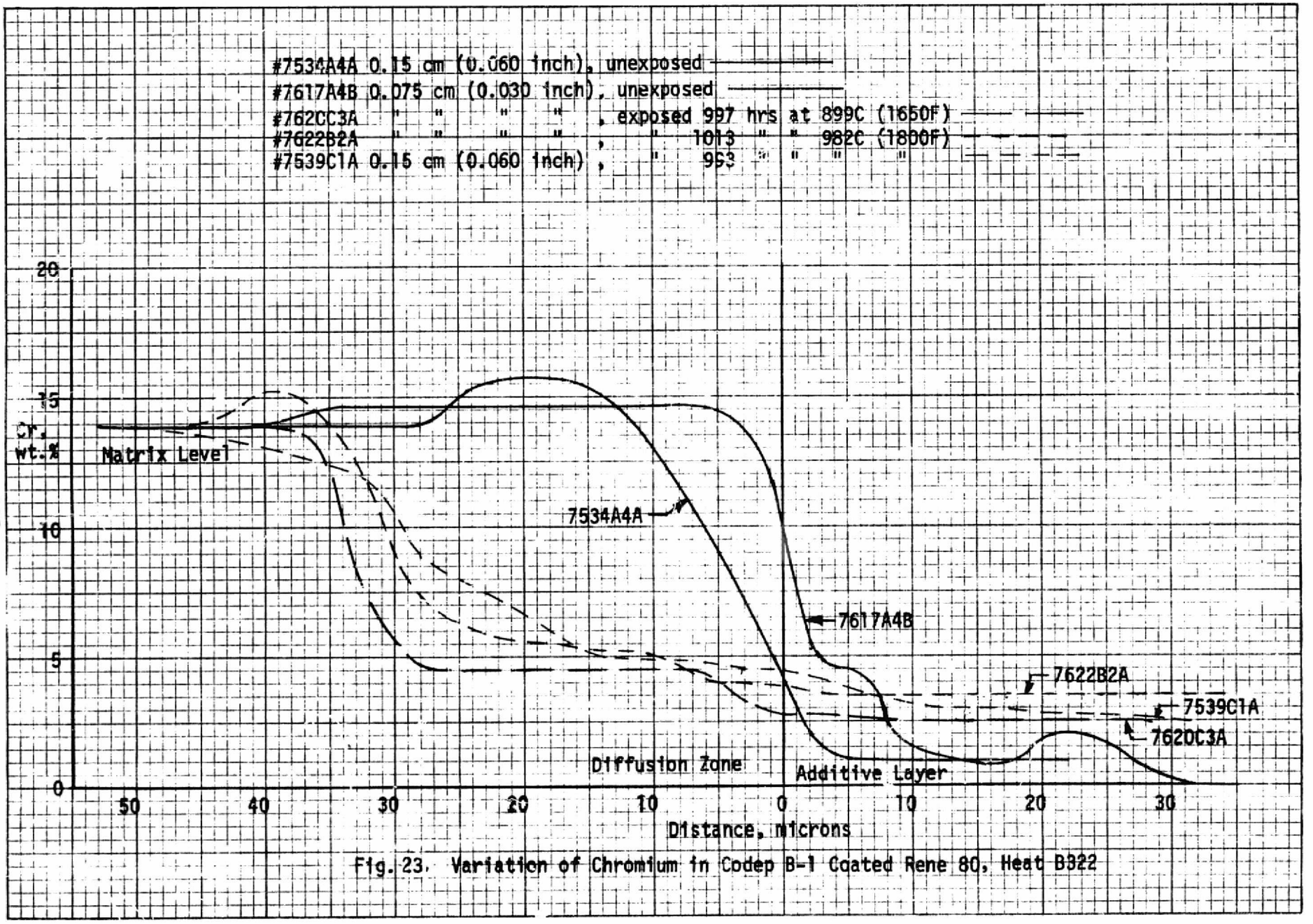


Fig. 23. Variation of Chromium in Codep B-1 Coated Rene 80, Heat B322

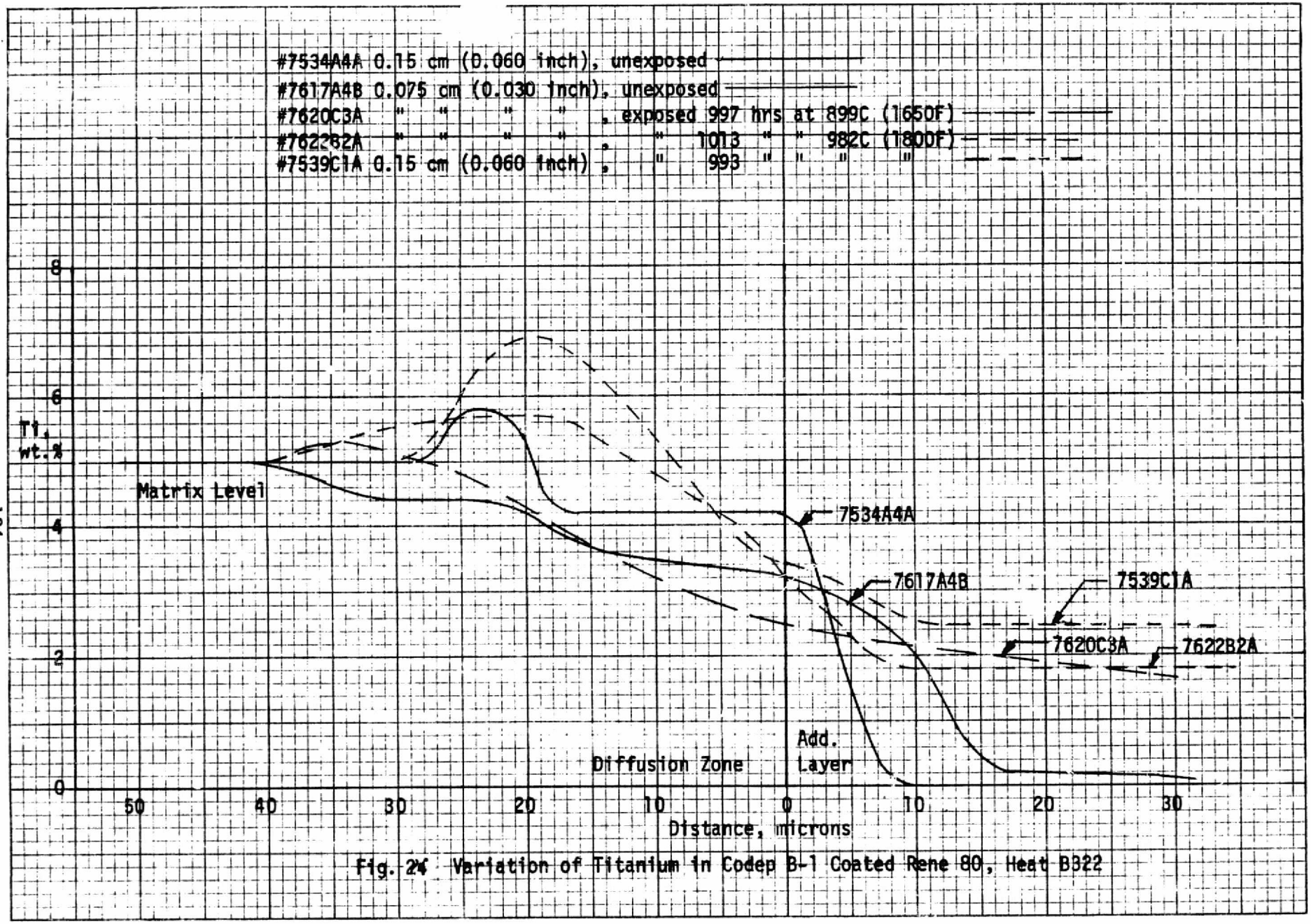


Fig. 24 Variation of Titanium in Codep B-1 Coated Rene 80, Heat B322

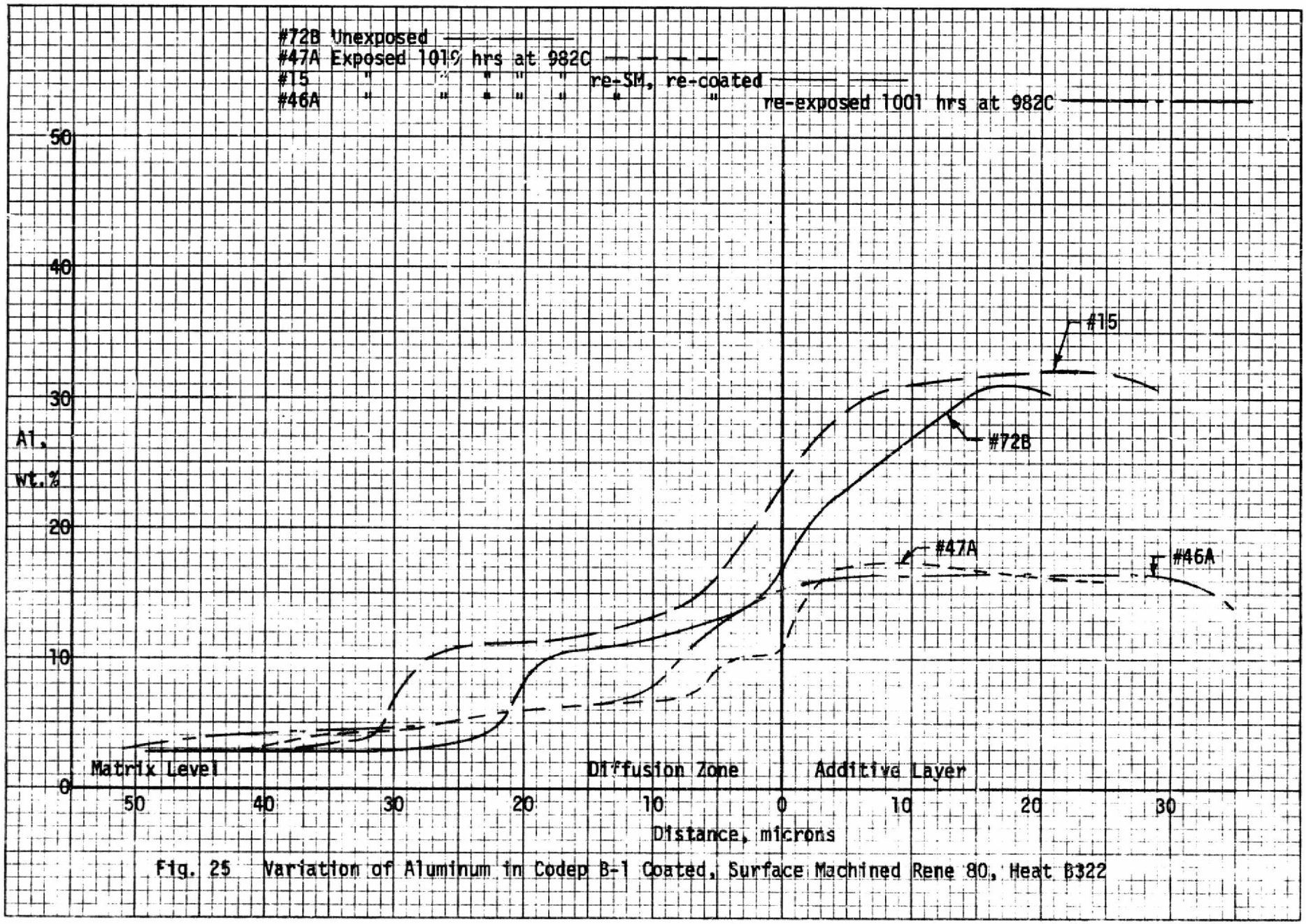


Fig. 25 Variation of Aluminum in Codep B-1 Coated, Surface Machined Rene 80, Heat B322

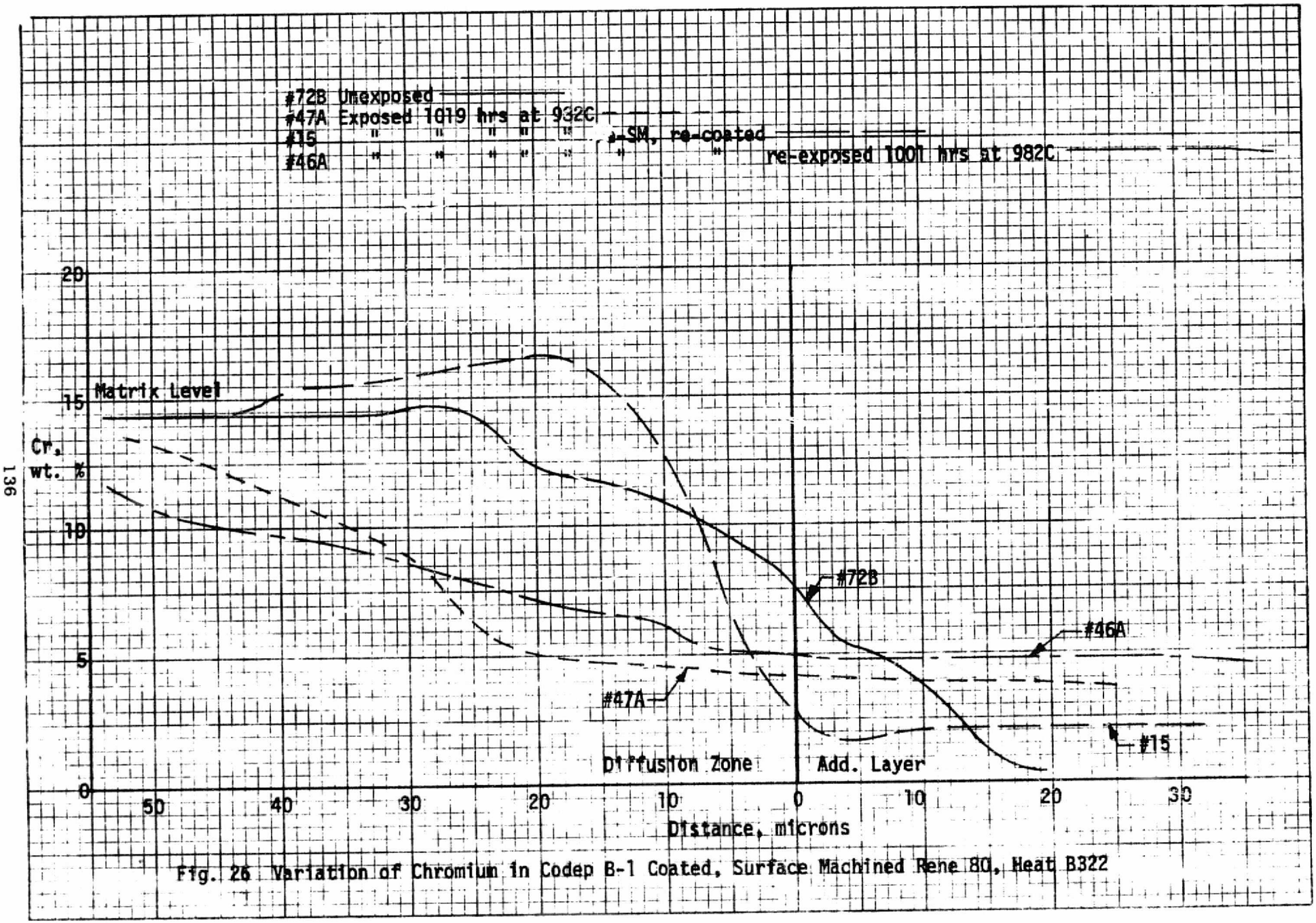


Fig. 26 Variation of Chromium in Codep B-1 Coated, Surface Machined Rene 80, Heat B322

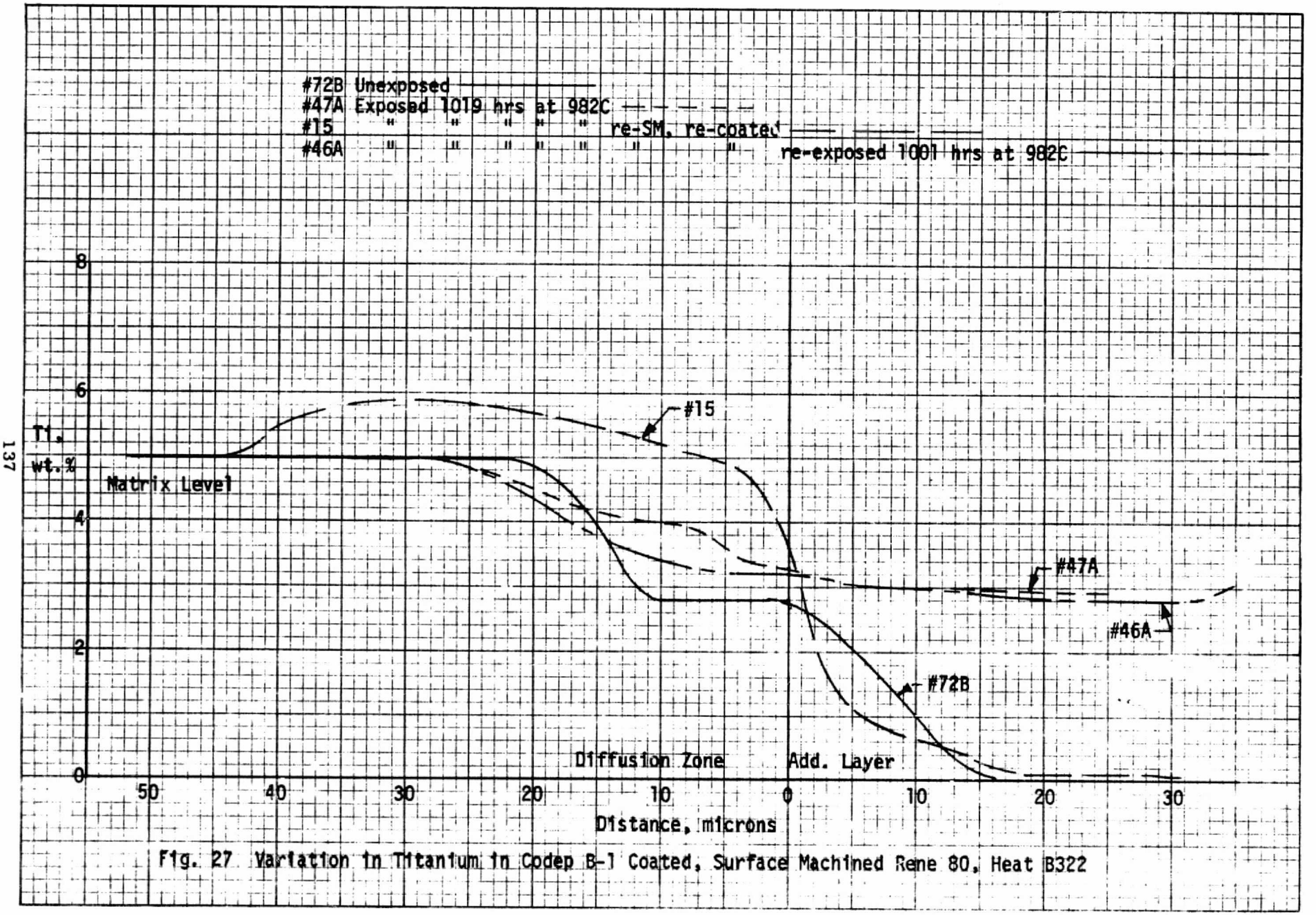


Fig. 27 Variation in Titanium in Codep B-1 Coated, Surface Machined Rene 80, Heat B322

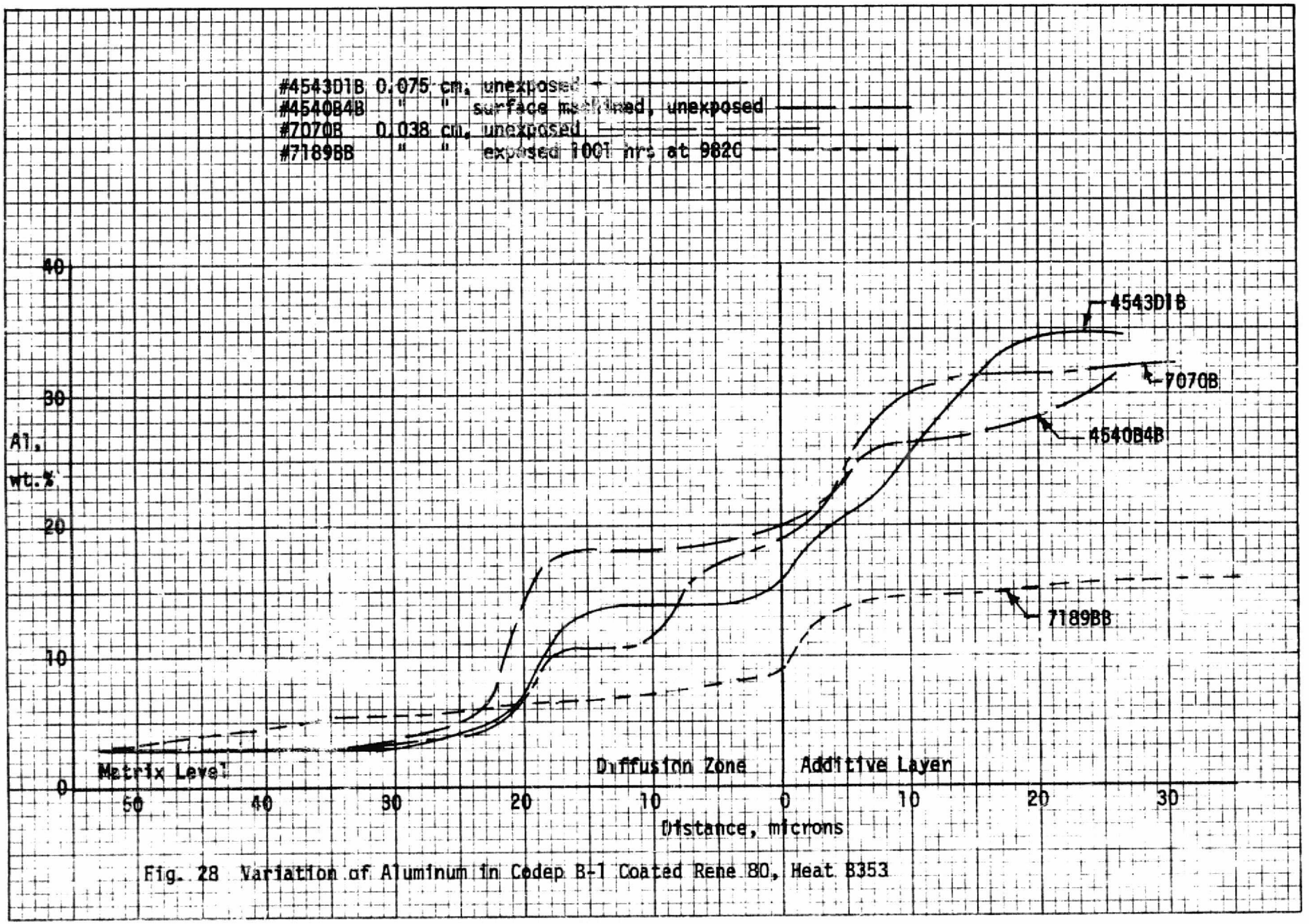


Fig. 28 Variation of Aluminum in Codep B-1 Coated Rene 80, Heat B353

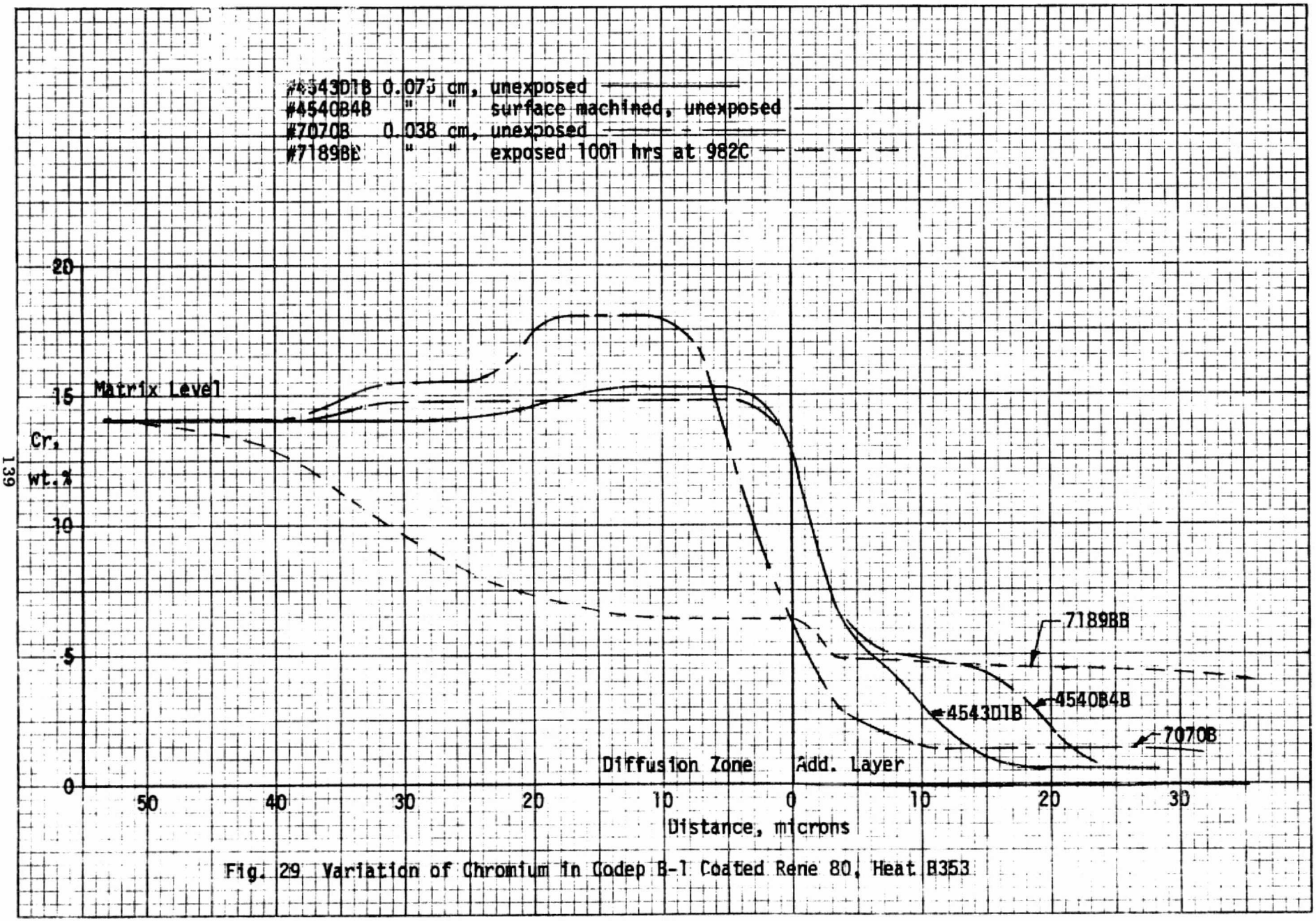


Fig. 29 Variation of Chromium in Codep B-1 Coated Rene 80, Heat B353

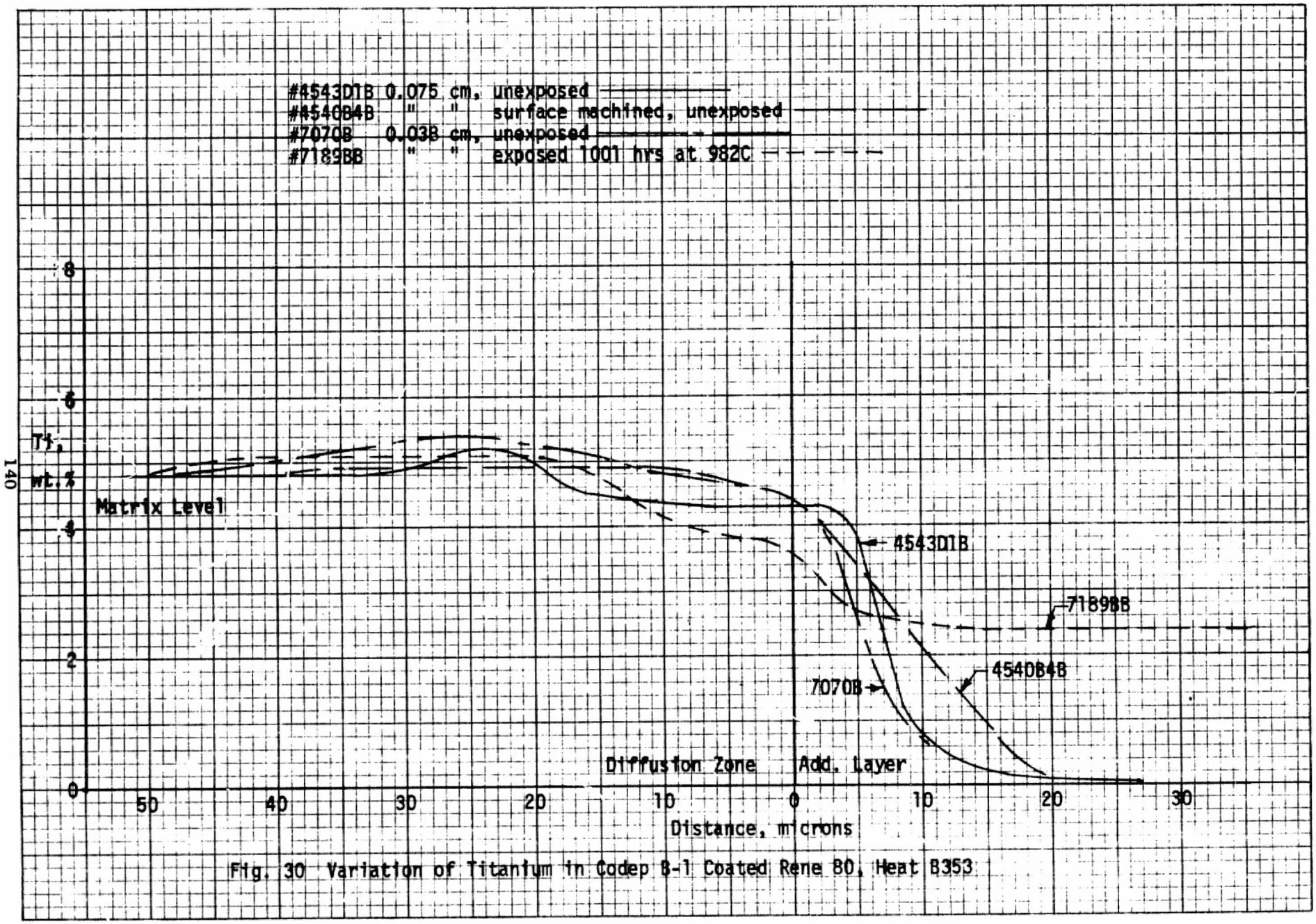


Fig. 30 Variation of Titanium in Codep B-1 Coated Rene 80, Heat B353

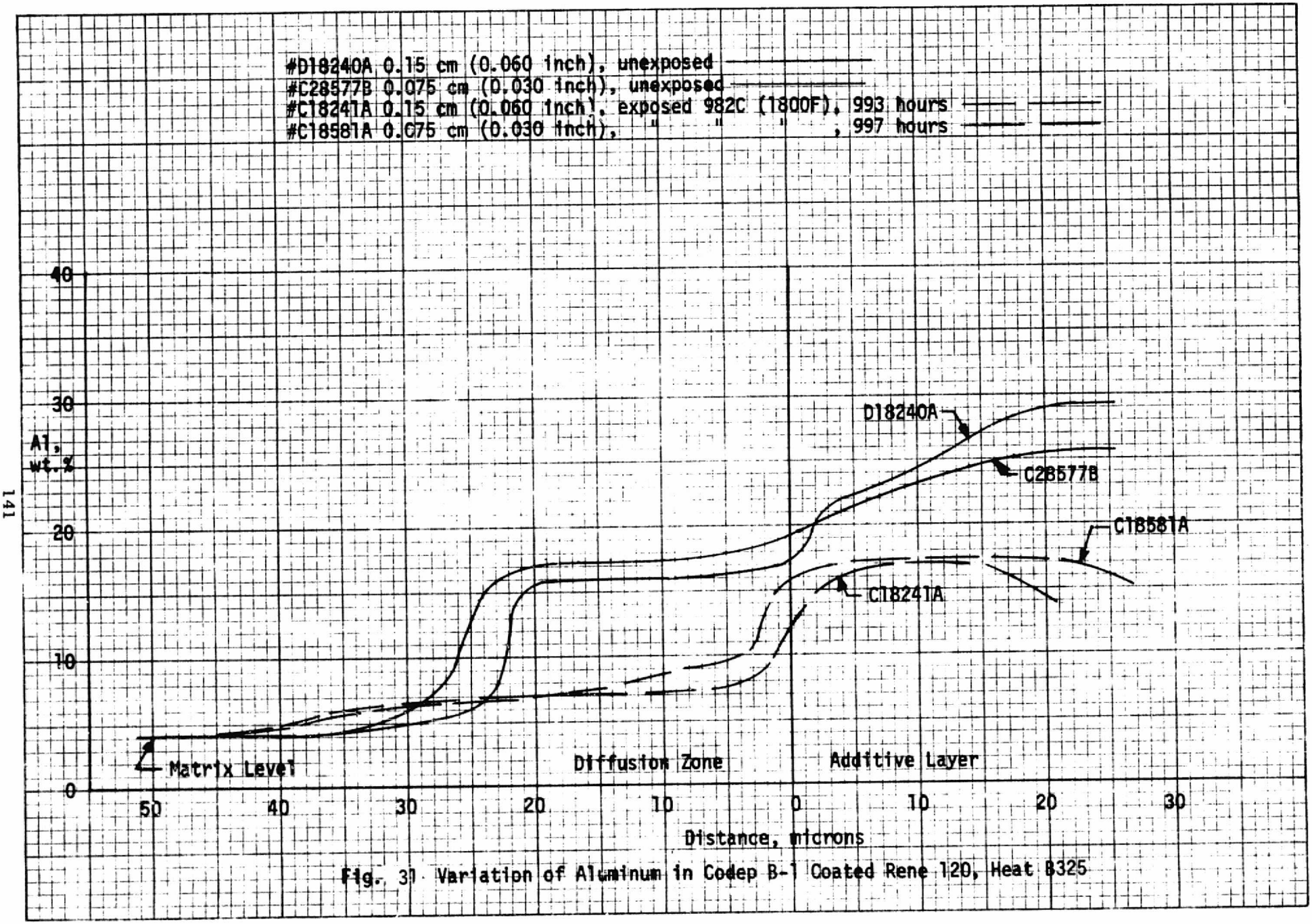


Fig. 31 Variation of Aluminum in Codep B-1 Coated Rene 120, Heat B325

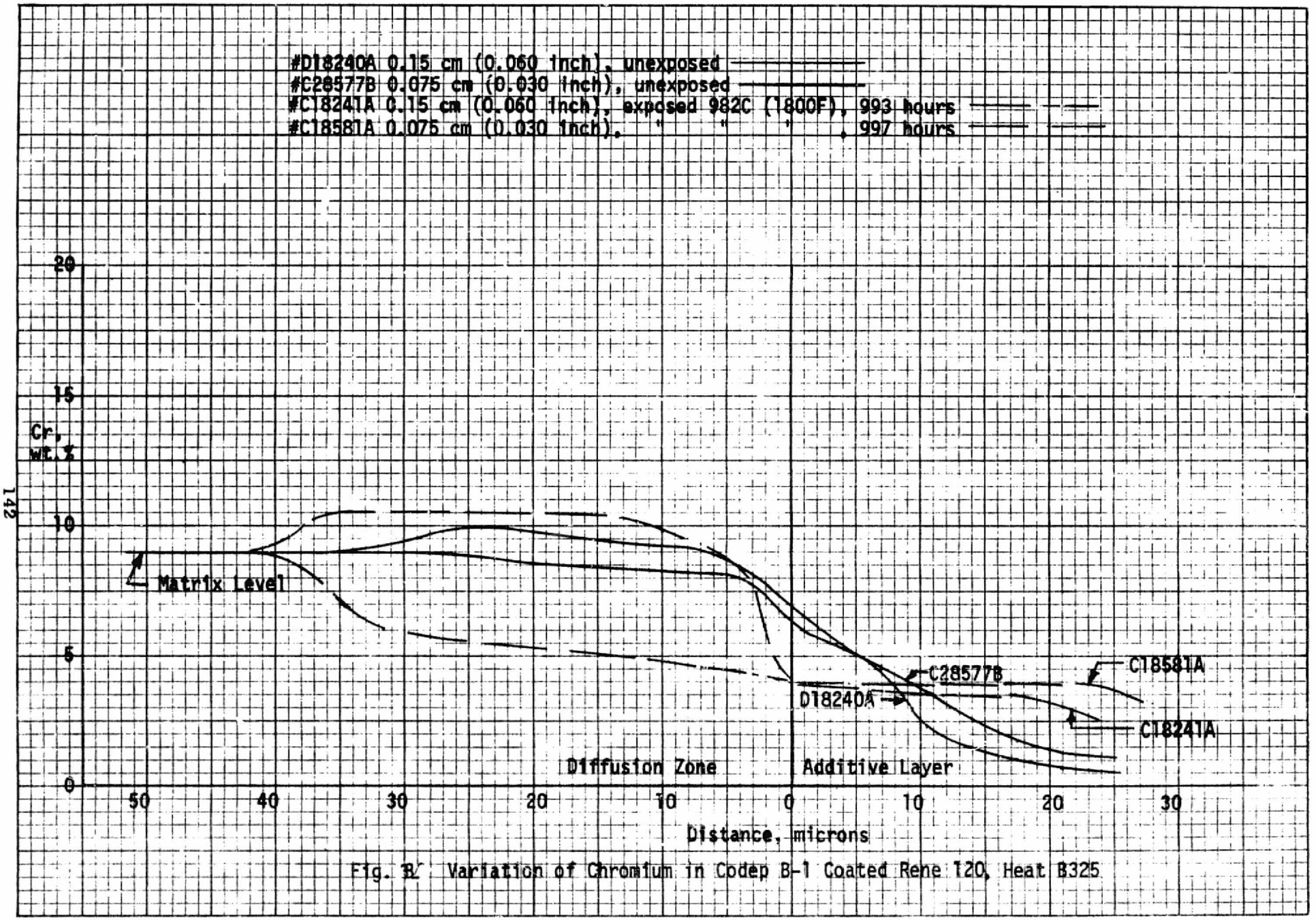


Fig. 8 Variation of Chromium in Codep B-1 Coated Rene 120, Heat B325

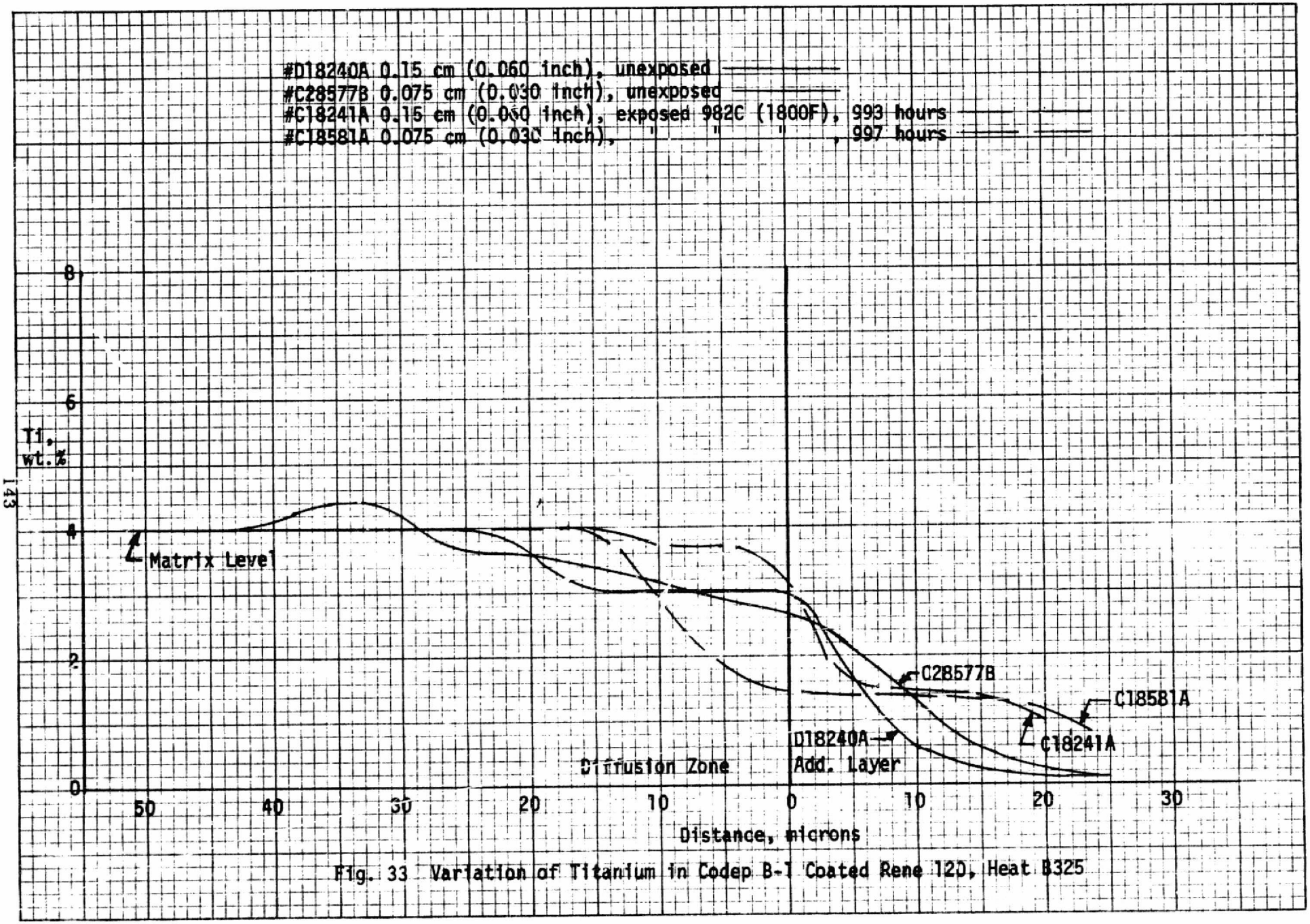


Fig. 33 Variation of Titanium in Codep B-1 Coated Rene 120, Heat B325

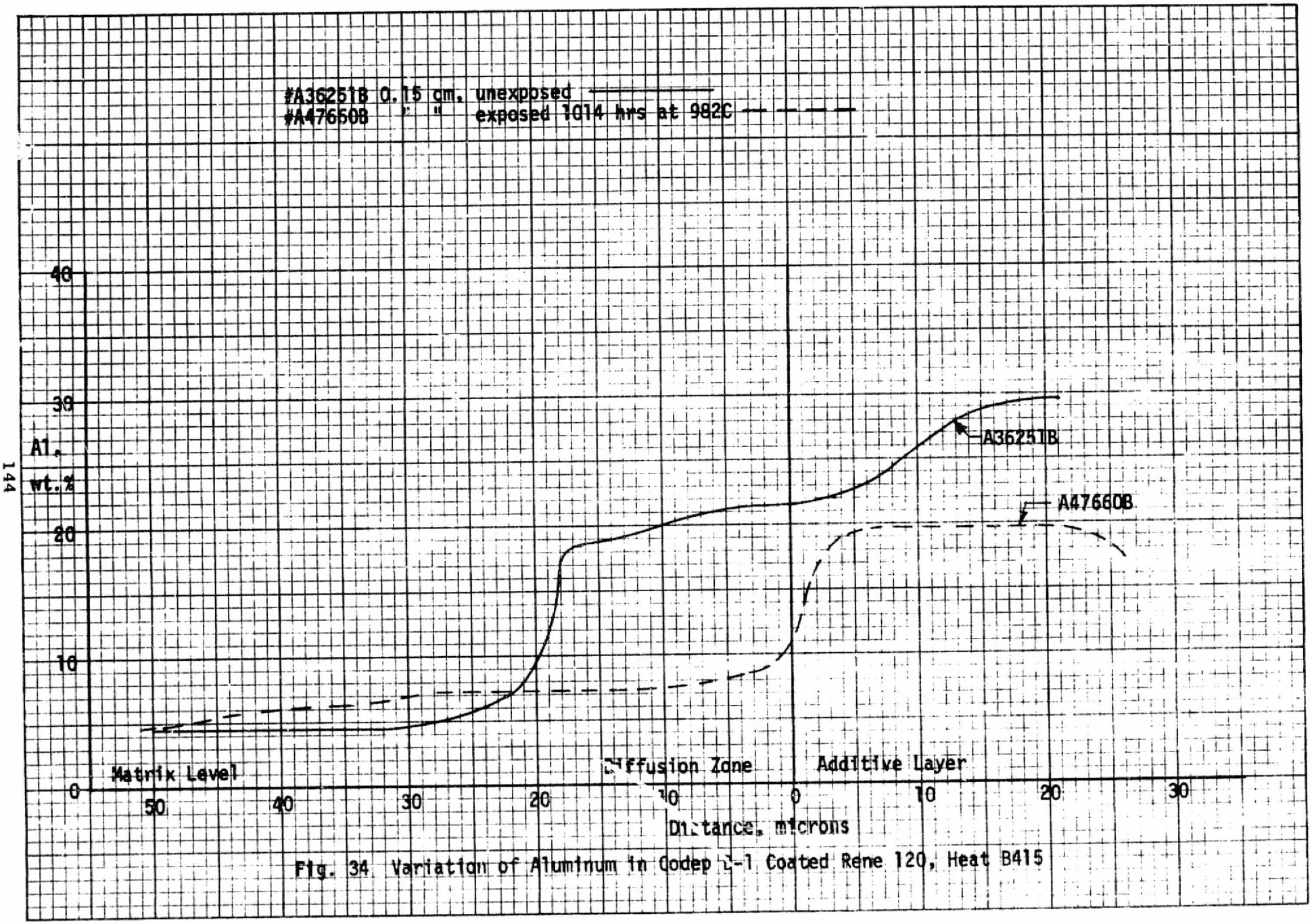


Fig. 34 Variation of Aluminum in Codep B-1 Coated Rene 120, Heat B415

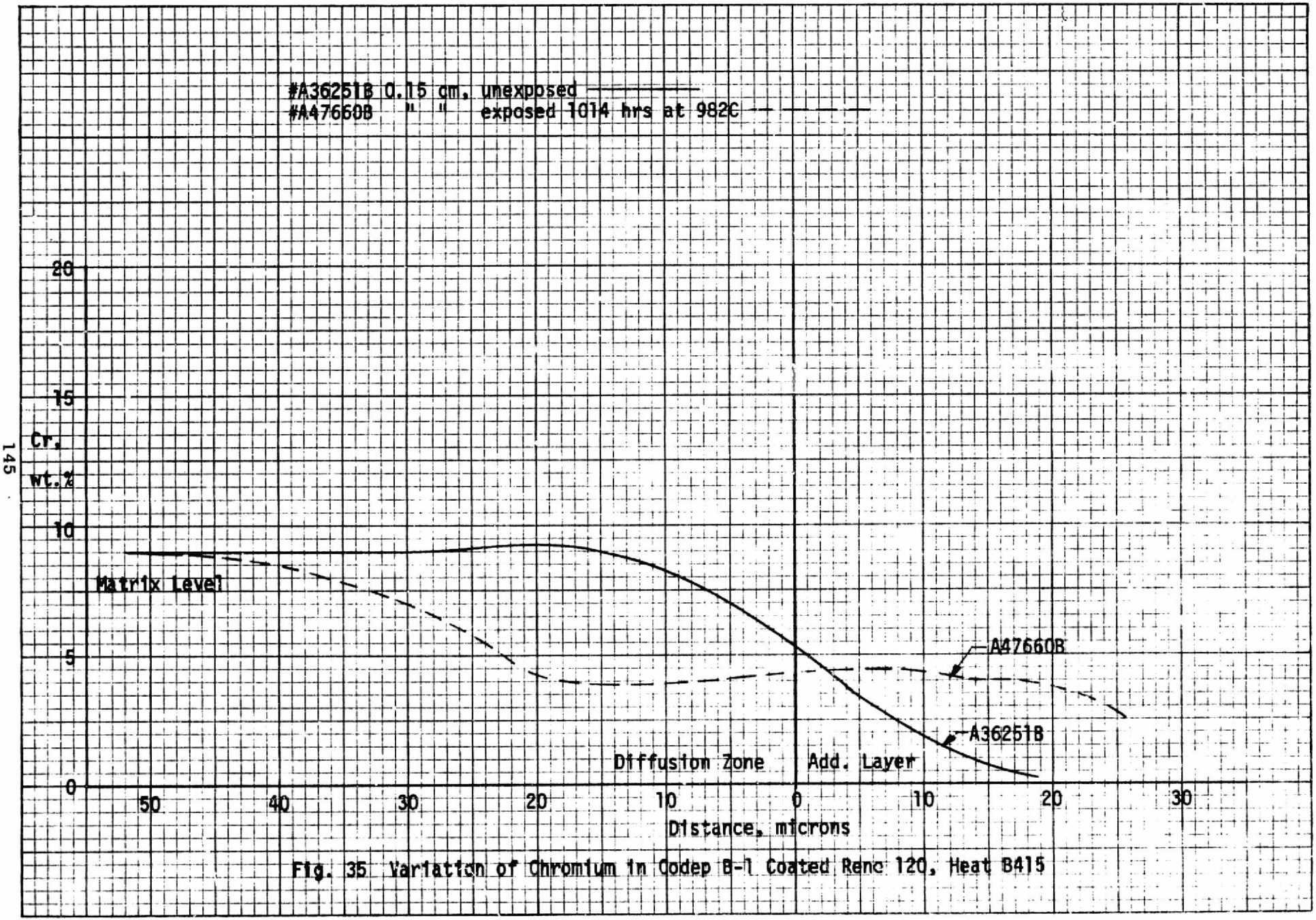


Fig. 35 Variation of Chromium in Codep B-1 Coated Rene 120, Heat B415

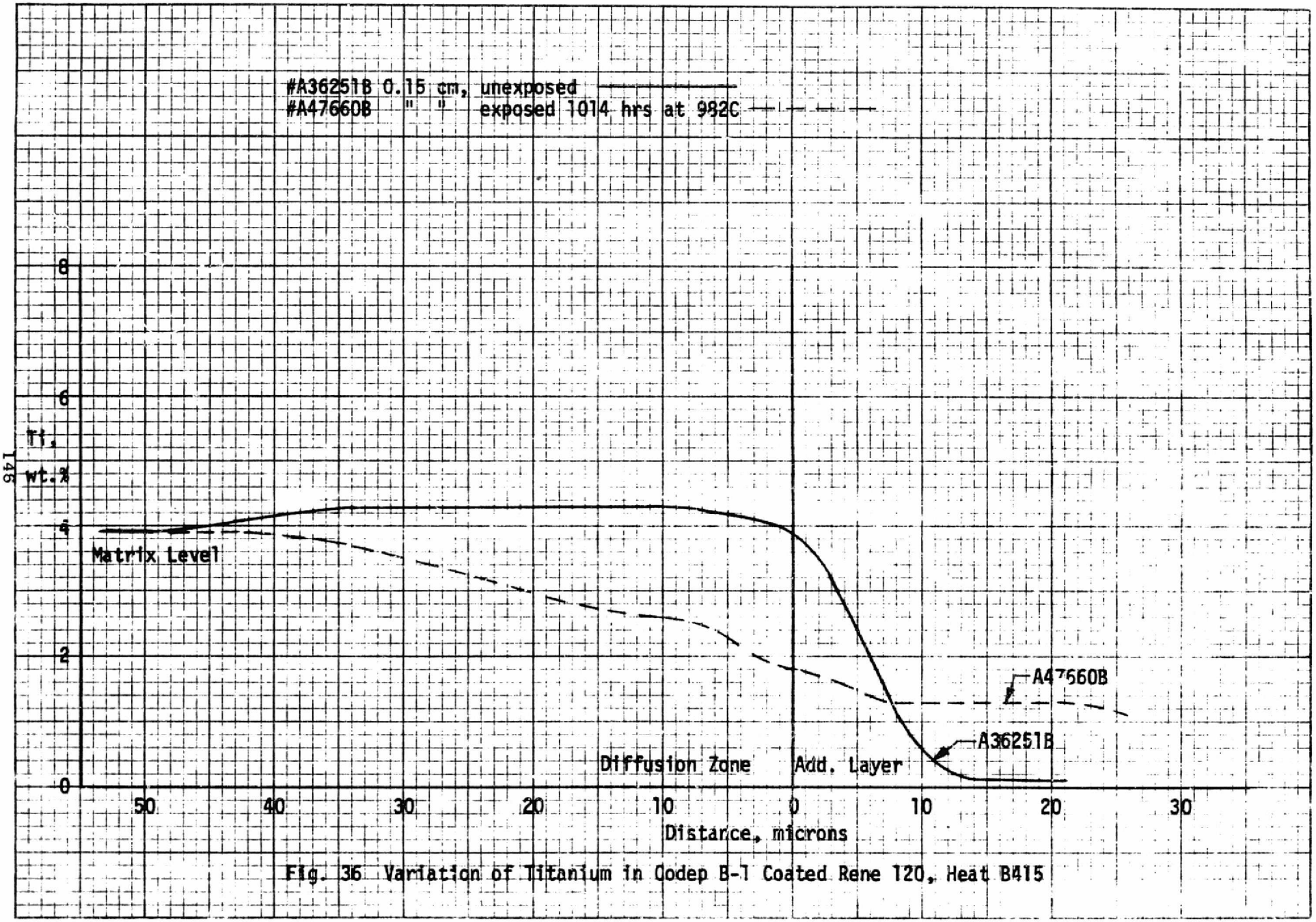


Fig. 36 Variation of Titanium in Codep B-1 Coated Rene 120, Heat B415